HEALTH

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BY

W. H. CORFIELD, M.A., M.D. (OXON.), F.R.C.P.

PROFESSOR OF HYGIENE AND PUBLIC HEALTH AT UNIVERSITY COLLEGE, LONDON;
MEDICAL OFFICER OF HEALTH AND PUBLIC ANALYST FOR ST. GEORGE'S
HANOVER SQUARE; EXAMINER IN SANITARY SCIENCE
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NOTE.

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The Sanitary apparatus described can be studied at the Parkes Museum of Hygiene in University College, London.

W. H. C.

10 Bolton Row,
Mayfair, W.

CONTENTS.

LECTURE I.

GENERAL ANATOMY—THE BONES AND MUSCLES.

BEFORE we begin the study of the Laws of Health, it is absolutely essential to know something of the human body, which is to be kept healthy.

Canon Kingsley, to whose suggestion the foundation of popular lectures of this kind is due, fully recognised this. He says, in his "Essay on Science and Health" (*Health and Education*, p. 13):—

"Why should not the experiment be tried, far and wide, of giving lectures on health, as supplementary to those lectures on animal physiology, which are, I am happy to say, becoming more and more common? Why should not people be taught—they are already being taught at Birmingham—something about the tissues of the body, their structure and uses, the circulation of the blood, respiration, chemical changes in the air respired, amount breathed, digestion, nature of food, absorption, secretion, structure of the nervous system,—in fact, be taught something of how their own bodies are made, and how they work? Teaching of this kind ought to, and will, in some more civilised age and country, be held a necessary element in the school course of every child,

just as necessary as reading, writing, and arithmetic; for it is, after all, the most necessary branch of that 'technical education' of which we hear so much just now, namely, the τέχνη, or art, of keeping oneself alive and well.

"But we can hardly stop there. After we have taught the condition of health, we must teach also the condition of disease, of those diseases specially which tend to lessen wholesale the health of townsfolk exposed to an artificial mode of life. Surely young men and women should be taught something of the causes of zymotic disease, and of scrofula, consumption, rickets, dipsomania, cerebral derangement, and such like. They should be shown the practical value of pure air, pure water, unadulterated food, and dry dwellings. Is there one of them, man or woman, who would not be the safer and happier, and the more useful to his or her neighbours, if they had acquired some sound notions about those questions of drainage on which their own lives, and the lives of their children, may every day depend. I say—women as well as men. I should have said women rather than men; for it is the women who have the ordering of the household, the bringing up of the children; the women who bide at home, while the men are away, it may be at the other end of the earth."

We shall first consider the human body, the parts of which it is made, and the working of those parts.

The study of the parts or organs of which an organic being such as man is made, goes by the name of Anatomy; the study of the working of those parts or organs goes

by the name of Physiology. We are about to study these two subjects together for the most part throughout the first few lectures, beginning from the simplest considerations.

The rough anatomy of a human being may be described as follows:—A human being consists of a head, trunk, and extremities or limbs.

THE HEAD consists of two parts. One is called the *cranium*, the other the *face*. In the cranium is contained an organ, and a very important organ, the brain. In the face we find, in the first place, the beginning of the organs which deal with the food, which we call the digestive organs (that beginning is the mouth, and the things that are contained in the mouth), the beginning of the organs that have to do with breathing, which we call the respiratory organs—that beginning is the nose. We find, besides these, in the face, certain organs of special sense,—the organ of taste in the mouth, the organs of sight, and the organ of smell, placed in the position in which we should expect the organ of smell to be placed, nearly at the beginning of the organs of respiration, nearly at the beginning of the tube through which air is taken into the body.

In the head we find also another pair of organs of special sense—the organs of hearing, which are situated in the walls of the cavity of the cranium.

THE TRUNK of human beings is roughly and ordinarily divided into two parts. The upper one is called the *chest* or *thorax*, and the lower one is called the

belly or *abdomen.* We shall see hereafter that this is not merely a popular division, but that it is really a rational division.

The chest contains, in the first place, the heart, and in the second, the lungs—one on each side of the chest. It also contains the great blood-vessels connected with the heart and lungs, part of the windpipe which leads to the lungs, and the continuation of a tube, the gullet or swallow, which leads from the mouth to the rest of the digestive organs. The head is connected with the chest by the neck, through which the tubes just mentioned pass, viz., the windpipe, which is connected with the lungs, and which connects the lungs with a cavity behind the mouth, into which the nostrils lead, and so with the nose; and the gullet or swallow, which is connected with the mouth, and passes down through the thorax into the next division of the trunk. In the lower division of the trunk, which we call the abdomen, there are contained, in the first place, the remainder of the organs of digestion, namely, the stomach, and the intestinal canal; the stomach being rather on the left hand side. On the right hand side of the abdomen is the liver. Besides these organs there is the spleen—an organ which is situated on the left hand side of the abdomen, to which the ancients attributed the property of causing anger, because they could find no other duty for it. Underneath the stomach, but situated rather behind it, is an organ we call the pancreas, which means all flesh; we eat the pancreas of the calf at table under the name of sweetbread. There are

also two other important organs in the abdomen, one on each side, called the kidneys.

I have said already that the chest and abdomen are popular divisions of the trunk; but there is a very good reason for this—namely that in us, and in all animals of the class to which we belong, the mammalia—so called because they nourish their own young—the chest and the abdomen are divided from one another by a partition, which goes by the name of the *diaphragm.*

I have mentioned the chief separate contents of the chest and abdomen. Besides these there is a double chain of nerves with knots (which we call ganglia) upon them, running down through the thorax or chest, and through the abdomen, behind all these organs. This double chain of nerves goes by the name of the sympathetic nerves. But if you took a human being, and examined him right through, from front to back, in the chest or abdomen, you would also find a chain of bones running from the head downwards behind the cavities of the chest and abdomen; and behind that chain of bones, a tube running right down, and inside that tube, a white cord which we call the spinal cord; and if you looked farther, you would see that the spinal cord is continuous above with part of the brain, through a hole in the walls of the cranium.

THE EXTREMITIES or limbs have no such cavities containing special organs as are in the head and trunk; they are solid throughout, except that they contain certain tubes. They, in fact, are made up of the same kind

of structures as the walls of the body generally, and these structures we will now consider.

In the first place, the whole exterior of the body is covered by what we call the skin. In the skin there are two important layers: there is the skin proper, called the *dermis*, which is soft, moist, very sensitive, and supplied with a great deal of blood. It bleeds when it is cut. There is also a covering to the skin proper, which we call the *epidermis*, because it is upon the dermis, or outside of the skin proper. This is drier, not sensitive, not supplied with blood, and consists of horny scales which are continually falling off. All the surface of the body is covered with it. Wherever there is an opening from the interior of the body to the external air, the skin, as we understand it, ceases, and another substance, or rather something that we call by another name, takes its place. All the cavities of the body that communicate with the external air are lined by a kind of internal skin, which we call the *mucous membrane*. This internal skin resembles the external in that it has two important layers. It has a deep layer, which is soft, sensitive, well supplied with blood, and a superficial layer, which is moist, but otherwise not unlike the superficial layer of the skin itself, as it is insensitive and not supplied with blood; thus, at all the openings between the internal organs that communicate with the external air and the surface, this mucous membrane, which lines these internal organs, joins the skin, so that we see that the organs already described as in the body, and many that we have not

mentioned, are, as it were, contained between these two skins.

The superficial layer of the mucous membrane is called the *epithelium;* so that in the skin we have the dermis or true skin, and the epidermis, which is sometimes called the scarf skin; and in the mucous membrane a deep layer, and a superficial layer called the epithelium. Underneath the skin of the body we find, in the first place, a more or less thick layer of fat, which is thicker in certain parts of the body than in others, and beneath that a number of structures that we call muscles or flesh.

We find this whether we take the extremities, or the walls of the body anywhere, and we find besides this a number of tubes containing blood, called *blood-vessels,* in all parts of the body below the epidermis or below the epithelium, and other tubes not containing blood, but a nearly colourless fluid, which, from its resemblance to water, is called *lymph.* These tubes go by the name of *lymphatic ducts.* Besides them we find white cords in almost all parts of the body, more or less directly connected with the brain or the spinal cord, which we call *nerves.* These are the structures that we find in the limbs, and also wherever we examine the walls of the body.

Such is a very brief outline of the more important organs of the body, and the way in which they are put together.

We will now pass on to consider parts of the body more particularly, and will begin with the bones. In

the young human body there are more than two hundred separate bones, but some of these grow together in the adult, so that several form one bone.

Bones and their Uses.—Bone, is in the first place, the hardest substance in the body (with the exception of the teeth), and contains three parts of mineral matter to only one part of organic or living substance. This composition gives great solidity to bony structures.

We call the assemblage of bones in the body the skeleton, and the uses of it are these:—The first is to protect the soft parts; the second to support them, and so keep the shape of the body; and the third to afford levers by means of which the parts of the body may be moved. All bones are constructed so that they shall be as light as possible, compatible with strength: they are either flat, like some bones of the skull, or long, like some of the bones in the limbs, or irregular in shape. Flat bones are made (in order to have the greatest strength with the least weight) of two plates of solid hard bone, with sponge-like bone between them. If you had a flat bone of one solid piece of the same weight as one of the bones of the skull, it would not be strong enough; and, on the other hand, if you had a flat solid bone as thick as one of the bones of the skull, it would be too heavy. So, too, the long bones are not solid pieces of hard bone; they have hard compact bone on the outside, and on the inside soft spongy bone, and in the middle of this a cavity containing marrow, which we call the medullary cavity. In this way the long bones have the greatest amount of strength combined

with lightness. Their section is, as a rule, more or less circular; they are, in fact, hollow cylinders, the strongest part of which is outside, a softer, more spongy part inside, and a hollow in the middle.

We will now refer to the bones that form the SPINAL COLUMN, which we call the back-bones. It is not correct to speak of the back-bone, as this spinal column consists originally of thirty-three separate bones, each of which is called a *vertebra*, two or more being called *vertebræ*. They each consist, in the first place, of a solid piece of bone called the body; a solid disc-shaped piece of bone, more or less oval in section, and harder, like any other bone, on the outside than on the inside. This body has what are called processes of bone projecting out from it backwards; they meet together a little distance from it, and form an arch. This arch, therefore, leaves a hole or ring between the body and the processes, so that you have in each vertebra, a body, processes, and a ring. From the back of the arch a process starts, called the *spinous process*, backwards, and it is from these spinous processes of the vertebral column that the old anatomists gave the name of the spinal column to this set of bones, and so the nervous cord which passes through the rings gets the name of the spinal cord. These vertebræ also have upon their processes places for joining them each with the vertebra above and the vertebra below, called articular or joining processes. When they are fitted together by means of these joining processes, as they are in the human body, the rings form a canal, and that canal is the spinal canal, which contains the

spinal cord. The canal communicates at its upper end with the cranial cavity, in which is the brain.

Now, to consider the parts of the vertebral column. These thirty-three vertebræ are divided in the following way. There are seven in the neck between the head and the chest, called *cervical* or *neck vertebræ*, and it is a very curious fact, that all animals that belong to the same class as we do (viz., the mammalia), with two exceptions, have each seven cervical vertebræ in the neck, whether they have, as in the case of the giraffe, very long necks, or, as in that of the whale, very short ones.

After these seven neck vertebræ, there come twelve in the back, called *dorsal* vertebræ, to which the ribs are attached. They belong especially to the thorax or chest; below them there come five large vertebræ, called *lumbar*, or the vertebræ of the loins. The bodies of the vertebræ get larger as we go down from the head to the last of the lumbar vertebræ. Then come five more, which in the child are separate from one another, and which in the adult grow together into one bone, called the *sacrum*.

After that there is in the adult, a little bone, called the *coccyx*, from its resemblance to the beak of the cuckoo; it is formed by the joining together of four small bones, which correspond to the bones of the tail in most other animals. That makes up thirty-three bones.

The first two cervical vertebræ have strange peculiarities. The first of them is called the *atlas*, because it carries the head. It has no body at all, properly speaking; but is merely a ring of bone, and the place

of its body is taken by a curious process called the *odontoid* or tooth-like process, which projects upwards from the body of the second vertebra or *axis*. It sticks up into the ring of the atlas; these two vertebræ are attached to the head by fibrous bands. This contrivance enables the head to be turned round upon the vertebral column without moving the rest of the vertebral column. The spinal cord, passing through the spinal canal, passes also through the ring of the atlas, and it is necessary in the turning of the head that the spinal cord should not be pressed upon, so there is a strong fibrous band, called the transverse ligament, which stretches from side to side and divides that ring into two parts. In the front part is the odontoid process of the axis, occupying the position that the body of the atlas would have done, and in the hinder part of the ring there is the spinal cord, so that this ring, although it is merely one ring, is divided by the transverse ligament into two parts.

Between the bodies of the vertebræ (except the first two) there are placed tough gristly plates or discs which are attached closely and firmly to the bodies of the vertebræ. They are soft in their inside, and their edges are so firmly attached to the bodies of the vertebræ, that the vertebræ can be broken rather than separated from them. They are called the *intervertebral discs*, because they are between the vertebræ. Besides that, the vertebræ are joined together by very strong fibrous structures, which we call ligaments; these pass right down in front of them, and also down behind their

bodies, inside the spinal canal, thus binding them all together.

Now what is the use of all this contrivance?

Firstly, the protection of the spinal cord. This is frequently given as the fifth or sixth object of the existence of the vertebral column. Why I call it the first is, because in animals that have no spinal cord, there is no vertebral column, and in animals that have a vertebral column there is a spinal cord.

The old naturalists divided animals into two classes, vertebrate animals, and invertebrate animals,—animals that have a vertebral column, and animals that have not.

You may think that it is a very extraordinary thing that the animal kingdom should be divided into two great parts, merely because of the presence or absence of a set of bones, but the reason is the one I have just mentioned, viz. that animals that have vertebral columns have spinal cords and brains, and animals that have not vertebral columns have not spinal cords and brains. This division of the old naturalists, although it merely rested originally upon the possession or not of this set of bones, is a sound one, and we have kept it.

The first use, then, of the vertebral column is the protection of the spinal cord. In the next place, it supports the head, the chest, and the upper extremities, which are attached to it; and it is supported by the lower extremities.

I want now to point out to you the reasons why it is constructed in the way I have described.

In the first place, the fact that it is made up of a large number of bones, separated by strong elastic discs, or rather connected by these compressible discs, gives it a certain possibility of movement, and this movement is attained without injury to the spinal cord.

Then another reason why the vertebral column is not made up of one bone, or why the spinal cord is not protected by one solid tube of bone, is, that it is very important that the spinal cord should not receive shocks, and it is very important, too, that the brain should not receive sudden shocks. Any shock communicated to a series of bones like this, separated by fibrous discs, containing softer matter in their interior, is lost before it gets very far, such shock being divided up as it were into a number of shocks, which get less and less the farther they go. We can jump on the ground without any severe shock being communicated to the spinal cord, and thence to the brain.

We will now pass on to the consideration of the bones of the head: they form THE SKULL, which is supported on the top of the spinal column. In the cranium, the part of the head in which the brain is contained, there are eight bones: the one in front goes by the name of the *frontal* bone; the two flat ones at the sides and top, because they are as it were the walls of the skull, are called the *parietal* bones; at the sides, lower down, are the two *temporal* bones, in which the internal organs of hearing are placed; the bone at the back part of the base of the cranium goes by the name of *occipital*; it is the bone which rests upon the

spinal column. (The two other bones of the cranium need not be noticed here.)

There is a large hole in the occipital bone which is continuous with the hole that passes down through all the rings at the back of the vertebræ; through that hole in the occipital bone the spinal cord comes up into the skull and joins the brain. So we see that in the cranium there is a large cavity which contains the brain, and is continuous through a hole with the spinal canal formed by the rings at the back of the vertebræ.

We may therefore say that vertebrate animals have a separate cavity in their body, containing the brain and spinal cord, and that the rest of their body is outside of that, while animals which have no brains or spinal cords have no such additional cavity.

In the skull, besides the cranial cavity, there is the face, in which there are fourteen bones.

The bones of the cranium and face, with one exception, are fastened together tightly, bone to bone, *i.e.* immovably fastened together; and the bones of the cranium form an arch over the brain, the strongest possible construction for the protection of the brain.

There are two ways in which they are fastened together—either the bones have irregular edges, and are joined so that the projections of one edge fit into the notches of the other,—a very secure connection, called, from giving the appearance of stitches, a *suture*—or else the edges are bevelled off so that the edge of one bone fits over the edge of the other in one place, and under it in another. The one bone in the skull which is not

fastened immovably to the rest of the bones, is the lower jaw.

We now come to the bones of the chest.

THE RIBS AND BREAST-BONE.—To the twelve vertebræ of the back there are attached on each side twelve pairs of thin curved bones called ribs. These bones are attached not one to each vertebra, but one between each two, *i.e.*, each of these bones is attached to two of the vertebræ of the back and to the disc between them. They are not attached so that they cannot move at all, but are so attached, by means of what we call a true joint, that they can be moved pretty freely.

A substance, softer than bone, which we call *cartilage* or gristle, is found at their other ends. These cartilages or gristles are attached in the case of the first seven pairs of ribs to a bone in the front of the chest called the breast-bone or *sternum*. The cartilages of the next three are attached to one another, and the other two ribs are not attached in front at all. These ribs and sternum form part of the walls of a kind of cage called the chest cavity, and protect the soft parts within the cavity of the chest.

Lastly, there are the bones of the LIMBS or EXTREMITIES.

In the upper extremity there is, in the first place, a triangular bone which goes by the name of the *shoulder-blade*. This is situated at the upper part of the back of the chest, and is not directly fixed to the vertebral column at all. In the second place, the *collar-bone*

which connects the shoulder-blade with the sternum or breast-bone.

In the upper limb, after these two bones, comes a long bone called the *humerus*, which is the bone of the arm proper. This bone has its globular head fitted to a shallow cavity in the shoulder-bone.

Thus the *upper* limb is only very indirectly connected with the vertebral column, because the main bone of the arm is joined to the shoulder-blade, and this, by means of the collar-bone, to the breast-bone, which is connected to the vertebral column by means of the ribs and cartilages of the ribs. In the *lower* limb it is very different: instead of the shoulder-blade and collar-bone, we have one bone on each side, which is called the *innominate* bone, and these bones, so far from being indirectly attached to the spinal column, are firmly attached, one on each side, to the bone that we have before referred to as being made of five vertebræ—viz. the sacrum,—and they are joined together in front; so that it will be seen that while the upper limbs are attached to bones which allow of a great amount of movement, the lower limbs are attached to bones which are very firmly fixed, and, in fact, support the vertebral column itself. In each of these two bones there is a deep cavity which receives the head of the main bone of the leg, called the *femur*, and you will note how admirably this construction is adapted for sustaining the body: one strong bone on each side, with the vertebral column wedged in between them, and the main bone of each leg stuck into a deep hollow in one of

these strong bones. Another thing to be noted, too, is, that whereas the main bone of the arm is straight, and its head fits quite loosely into a slight cavity at the end of the shoulder-blade, the thigh-bone is bent at an angle, and its head fits into a deep pit, so that the two thigh-bones, on account of the angles at which they are bent, form an arch with the bones in which they are set, and the lower part of the vertebral column is wedged in, as it were, at the crown of this arch.

We will now take the remainder of the upper limb and the remainder of the lower limb. In the fore-arm there are two bones, and in the fore-leg there are two bones; so far they resemble one another. After these two bones in the fore-arm comes a set of small bones called the wrist-bones, eight in number, and there are, likewise, in the lower limb a set of small bones which are called the ankle-bones, seven in number. In the upper extremity, after the wrist-bones, come the bones in the hand, five in number, and after them bones in the fingers, three in each finger and two in the thumb. In the lower extremity, after the ankle-bones, we have the bones in the foot, five in number, and then the bones in the toes, three in each toe, except the great toe, in which there are two; so that it will be seen that in the upper and lower extremities there are considerable resemblances in the way in which they are built up, as to the number and arrangement of their bones, at any rate.

But let us look a little further. The upper limb is

one which requires the greatest possible amount of movement; it is a prehensile member, and note how this is provided for. The bones of the fore-arm are called the *radius* and the *ulna*. When the arm is hanging down with the palm of the hand forwards, the radius is on the outer side of the fore-arm and the ulna on the inner. The main bone of the arm is joined to the ulna. The radius has a disc-shaped head, rather like a thick gun pellet, which is capable of moving in a groove on the inner side of the head of the ulna. The lower end of the radius is much larger than the upper end. To the lower end of the radius or outside bone of the arm the first four bones of the wrist are joined, and the other four bones join on to them, and the hand bones are joined to these, so that the hand is attached, by means of the wrist, to the end of this radius or outer bone of the arm, and has very little to do with the other bone, whereas the other bone is joined on to the main bone of the arm. Therefore, when the head of the radius is turned round in the groove of the ulna, it carries the hand with it, because the hand is attached to it, and so the hand is turned round.

In the lower limb, between the knee and the ankle, there are two bones, the inner one, a very strong bone, called the *tibia*, on to which the lower end of the thigh-bone joins, and the other called the *fibula*, a very thin bone which rests along on the outer side of it. There is no turning round between these two bones at all, and so far from the fibula being joined on to the ankle as the radius is joined on to the wrist, it is especially the

tibia, the same one that is joined on to the thigh-bone, that joins with the ankle.

Now the hand is joined on to the outside bone of the arm in a straight line, and it is joined on comparatively loosely, so that you can move the hand very rapidly in many directions, as required, but, on the other hand, the foot is joined on to the bones of the leg at right angles. When the foot is planted upon the ground in a horizontal position these bones are in a vertical position, at right angles to the foot.

The bones of the fore-leg are joined to one bone among the ankle-bones (not to a row, as in the wrist), and another of the ankle-bones projects backwards and so lengthens the basis of support, forming the heel; so it will be seen that in the lower limb the bones are arranged in such a manner as to bear weight, while, on the other hand, the bones of the upper limb and hand are arranged so as to allow the greatest amount of movement. Further, the bones of the ankle and foot are disposed in an arch, thus showing that in the construction of the foot itself you have the strongest construction that we know of for supporting the weight of the body.

Thus we find this construction in the foot, in the pelvis, and in the cranium, the bones of the skull being so arranged in order to protect the brain.

JOINTS.—Bones are joined together in several ways. In the first place, they are joined together by what we call fixed or immovable joints, such as have been explained in our description of the skull. Then there are mixed joints, which are neither fixed nor very movable,

such as we have explained in the vertebral column, and the joints between the collar-bones and breast-bone.

Further, there are what are called true joints or movable joints, which are constructed as follows:—Two pieces of bone would rub together harshly, so the ends are covered with a softer substance—gristle or cartilage—and between the cartilage of each bone there is placed a little bag of membrane, closed on all sides, which is capable of secreting fluid in its inside—that fluid is called *synovia*, and the bag itself, the *synovial membrane*. There is no way into this bag and no way out of it, and it is placed in between the ends of the two bones, and so keeps the joint continually moist and soft.

Besides that, there are structures passing from bone to bone which bind them together, and because they *bind* are called *ligaments*. They are made of a tough substance, called fibrous tissue; it is the white, shiny substance often met with in a joint of meat; sometimes there are so many of these ligaments as to surround the whole joint,—for instance, in the hip-joint,—when they are called the *capsule* of the joint.

MOVEMENTS.—In all true joints the bones *glide* one over the other, and in certain joints that is the only movement possible, as, for instance, between the bones in the wrist. In other joints an angular motion is also allowed, and these are called *hinge-joints*—such are the elbow-joint, the knee-joint, and the finger-joints.

In others one bone turns round upon another, and such are called *pivot-joints;* an example of this is

found between the first and second vertebræ—the first vertebra, with the head upon it, turns round on the pivot stuck out of the second vertebra,—it is called the motion of *rotation*.

Another example of the movement of rotation is found in the joint between the radius and ulna.

Besides these, there is the *ball-and-socket joint*, which allows of the greatest amount of movement. In this, the head of one bone is globular, shaped like a ball, and fits into a cavity or hollow of another. As examples of this, I may refer to the shoulder-joints and the hip-joints. In these there is yet another movement allowed which we have not mentioned, and that is the movement by which the whole limb is moved round an imaginary line; this is called the movement of *circumduction*.

The movement of rotation is much greater in the case of the thigh-bone than it is in that of the main-bone of the arm, because the thigh-bone is bent so that it can be turned round much more readily than the arm-bone, which is very nearly straight; this makes up for the want of rotation in the fore-leg; on the other hand, rotation of the main-bone of the arm is not needed, because we have the maximum power of rotation in the fore-arm.

I have before explained that one of the uses of the bones in the body, and especially of the long bones, is to act as levers by which the parts of the body can be moved. The bones cannot move by themselves, and I am now going to describe the substance, the office of

which is to move the bones, and so to move the different parts of the body. That substance we call *flesh* or *muscle.* Flesh or muscle is made up of bundles of fibres, which are surrounded by strong, tough, fibrous structure: a set of such bundles again surrounded by another strong fibrous structure goes by the name of a muscle, so that a muscle consists of bundles of fibres, of what we call muscular tissue, enveloped in a strong fibrous membrane.

As a rule, this strong fibrous membrane at each end of the muscle is fixed into bone, and frequently at one or both ends of the muscle, assumes the form of a cord, or, as we call it, a *tendon* or *sinew.*

Flesh or muscle has a peculiar property, which is that it contracts when it is irritated; contracts, as we say, under the application of stimuli; this irritation may be mechanical, chemical, or electrical; cooling of the muscular tissue produces a like effect.

When either of these kinds of irritation is applied to a muscle it contracts, *i.e.* it shortens, the distance between its two ends becomes less, and it becomes thicker. Not only does the stimulus affect the whole muscle, but each fibre.

It is clear when this happens that one or both of the bones to which the muscle is attached must move, or else it would be torn away from its attachment to the bones. The bones are moved because the muscle joined to the bones shortens, and therefore the two ends of the muscle must be brought nearer together, and that can only happen when either one or both of the bones is moved.

There is another stimulus by which the muscles we are now considering, viz. the muscles that constitute the flesh of the body, the muscles by which the levers are caused to move the different parts of the body, are made to contract, and that other stimulus is the *will*.

The stimulus caused by the will acts through an apparatus not yet described, namely the nervous system. The stimulus exercised by the will can cause these muscles to contract, and therefore the different parts of the body to be moved, and so these muscles that are under the influence of the will go by the name of *voluntary muscles;* they are muscles over which we have control by means of the will, so that we can make them contract whenever we choose. We shall see that there are a great many muscles over which we have no control by means of the will, and these are called *involuntary muscles;* there is a considerable difference in structure between voluntary and involuntary muscles, which need not be described here.

There are a great many voluntary muscles over which we have no control, but that is our fault, and no fault of the muscles. We all have muscles, for instance, which, if we could use them, would make our ears move; if we had exercised those muscles from childhood we should now be able to move our ears at pleasure, and there are a number of people who can.

The voluntary muscles then are placed at the outside of the body, in its walls and in the limbs, on both sides of them. Another function that they have to perform is to help to protect the joints, and they are to

a certain extent a protection to some other parts of the body, for instance to some of the blood-vessels.

Muscles that by contracting bend a part, are called *flexors*. Muscles that by contracting straighten a part, are called *extensors*, so that the flexors and extensors are opposed to one another. Muscles, when they move one bone round another, are called *rotators*. Muscles which move a whole limb round an imaginary line are called *circumductors*. Muscles which bring a limb towards the body are called *adductors*. Muscles which take a limb away from the body are called *abductors*.

Although I must tell you that every single muscle has its own separate name, yet these six names are sufficient for our purpose.

By muscles we are enabled to maintain our bodies in an upright position. The skeleton will not stand upright, and a dead body will not stand upright, although the muscles are there; and that shows that the muscles are continually being exerted, in order to enable us to balance ourselves.

The muscles of the lower limbs, and of the trunk, are continually exerting an opposing influence to one another. We could not stand upright if certain of the muscles of the lower limbs and trunk were not more or less in a state of contraction.

The large muscles in the calf of the leg are in a sufficient state of contraction to prevent us falling forwards, and the muscles in front of the thigh are in a sufficient state of contraction to prevent us falling backwards, and so on with the muscles of the trunk.

So you see that these muscles keep the body upright by being in a state of contraction, exerting an opposing power to one another, and in that way they manage to balance the body. You can now see, too, why we cannot go on standing up always; supposing a dead person, or a skeleton, could stand upright, there would be no reason why we could not stand upright for a week. But we cannot do this, because we could not support the fatigue that these muscles would have to undergo by such continual contraction.

LECTURE II.

THE CIRCULATION OF THE BLOOD.

You all know there is a fluid in the body which we call blood, and that the object of this fluid is to nourish the tissues of the body; you can see, therefore, that it is necessary that this fluid should be conducted in some way or other to all parts of the body, and this is done by means of what we call the Circulatory Apparatus, which consists of a pump and pipes. The pump is the *heart*, and the pipes are the *blood-vessels*. A person's heart is about the size of his closed fist. It is conical in shape (or heart-shaped if you like), having therefore a *base* and an *apex*. It is situated in the thorax or chest, between the lungs, rather more on the left side than on the right. Its base is turned upwards towards the right, and its apex is downwards towards the left. It is almost entirely surrounded by a membrane something like those bags of membrane described as being inside the true joints, a closed bag which nearly surrounds the heart, although the heart is entirely outside of it.

I want you to understand that, because most of the internal organs of the body have bags like this surrounding them. The bag just referred to, because it is round the heart, is called the *pericardium*; the lower part of this bag is attached to the diaphragm.

The heart has two sides, with a cavity on each side, and the two sides do not communicate with one another directly; they are completely separated by a partition that passes down from the base to the apex, and is called the *septum*. The walls of the heart and this partition are all made of muscle, but it is a muscle over which we have no control by means of the will, and it is therefore, unlike the muscles of the limbs, an involuntary muscle.

The walls, then, and the partition, are all made of muscular tissue, and the partition divides the cavity of the heart completely into two, one on the right side and one on the left; each of these is subdivided into two cavities, which do communicate with one another. The upper cavities are called *auricles*, because they have little appendages, which look like ears, belonging to them. Two auricles then—the right auricle and the left auricle. The lower cavities, which communicate with the upper ones, are called *ventricles*—the right ventricle and the left ventricle.

Between these cavities, on each side, there are flaps of membrane, between the right auricle and the right ventricle, and between the left auricle and the left ventricle—flaps of membrane which are continuations of the membrane which lines the interior of these cavities—just as there is a membrane outside the heart, so there is a membrane lining the interior. This is called the *endocardium*.

The flaps of membrane we call *valves*. On the right side, between the right auricle and the right ven-

tricle, there are three flaps, and the valve on that side goes by the name of the *tricuspid*, or three-pointed valve.

On the left side there are only two such flaps of membrane, and they go by the name of the *bicuspid* valve, sometimes called the *mitral* valve, because it is similar in shape to a bishop's mitre. These flaps hang downwards into the ventricles, and are fastened by means of fine tendinous cords to little muscular projections from the walls of the ventricles.

Into the auricles, on each side, there open large blood-vessels. Into the right auricle two large blood-vessels open. They are called large *veins*. I will tell you why by and by. Into the left auricle four veins open, and at the openings of these vessels into the auricles there are no valves,—they open straight into the cavities of the auricles.

From each ventricle there rises a large vessel, which in each case is called an *artery*. The vessel that rises from the left ventricle is called the *aorta*, or great artery of the body. The vessel that rises from the right ventricle is the artery which goes to the lungs, and is called the *pulmonary artery* for that reason.

At the beginning of both these vessels there are three little pouches of membrane placed round the vessel. The interior of these pouches looks up into the vessel, and they are called the *semilunar* (half-moon-shaped) valves, from their shape.

We will now pass on to the consideration of the *action* of the heart, and of the tubes that are connected with it. Suppose we begin with the left ventricle. When

the left ventricle is full of blood the muscular walls of that ventricle contract and squeeze the blood that is in it against the flaps of membrane that hang down from the auricle, forming the bicuspid or mitral valve, which are so tied down that they cannot be turned inside out, and the pressure of blood on those flaps closes them like a floodgate, so that the blood cannot go from the ventricle into the auricle; but it is forced also against the little pouches of membrane or valves at the beginning of the great artery of the body, which is called the aorta; so that the pressure of blood on the under side presses them against the walls of the aorta, and as the ventricle contracts it squeezes the blood past those little valves into the aorta. This is a strong tube, with very elastic walls. In its walls there is a great deal of what we call *elastic tissue.* It is full of blood already, and when the ventricle squeezes three ounces more into it, of course the walls of this elastic tube are bulged out. As soon as the ventricle has emptied itself it finishes contracting, and its walls begin to relax; then the elastic walls of the aorta recoil upon the blood and squeeze it; and as when any pressure is exerted upon a fluid, it presses equally in all directions, so the blood is pressed both ways, and is forced back against these little flaps of membrane at the beginning of the artery, pressing them all against one another, so that the force of the blood backwards towards the heart by the recoil of the elastic walls of the artery closes those little valves; the blood then cannot go back into the heart, and so the pressure caused by

the recoil of the artery drives it forwards into another part of the artery and bulges that, and then that in its turn recoils and presses upon the blood, but as there is sufficient blood behind it to resist the pressure, it must go forward, and it continually goes forward like a wave.

This artery, the great aorta, gives off branches. The first branches that it gives off are two small branches a little above the semilunar valves, and these go into the substance of the heart. They are called the *coronary* arteries, and the blood which goes through these two little branches into the walls of the heart nourishes the walls themselves. Then the aorta turns round, forming an arch, and gives off branches to the head and arms. You will recognise the name of the branches to the head, viz. the *carotid* arteries. Then it goes down through the chest close to the vertebral column, giving off branches as it goes to the chest-walls, etc., and passes through a hole in the diaphragm into the abdomen, giving off branches to the different organs in the abdomen; lastly, it subdivides into two branches, one for each lower limb. Its branches go on giving off smaller branches the farther they go, so that from that great artery branches go to all parts of the body. This is the artery which starts from the left lower cavity of the heart.

These branches become finer and finer, and when they become very fine they have a considerable quantity of muscular tissue in their walls, and this is involuntary muscular tissue; they end in still finer tubes of what we call structureless membrane, which, because of their ex-

ceeding fineness, are named *capillary* vessels, from a word meaning a hair, though they are much finer than a hair.

The blood then is pumped into the great aorta, and, by contrivances already explained, forms a kind of wave which goes on and extends the different pieces of artery on its way, each piece of artery recoiling upon it and pushing it farther, and it goes on right into the very small arteries. We can actually detect that wave in some places, as in the wrist, where we are able to feel the pulse, which is caused by the wave we have just been describing.

When the blood passes through the smallest arteries, and is squeezed by their muscular walls into the capillary vessels, this wave is lost, and through these it travels at a perfectly uniform rate. Now there are several reasons for that. One reason is, that the farther you go from the heart the greater the sectional area of all the arteries becomes; the smaller the arteries get the more there are, and they are immensely out of proportion to the size of the artery at its beginning, so that if you take all the small arteries at a certain distance from the heart their area is very much larger than the arch of the aorta as it leaves the heart, so that the blood that is started through this large artery very fast must go very slowly when it comes to the small ones, and consequently when it reaches the capillary vessels it goes quite slowly and uniformly, and you can tell how it is that though this artery is filled with blood by jerks of three ounces of blood at a time, when it reaches the capillary vessels it should run uniformly and slowly; because, suppose you had a large

cistern with a small tap in the bottom of it, and you filled this cistern with water by throwing in buckets of water at the rate of one every half minute, and turned the tap on, you would be throwing in water just in the same kind of way as the blood is pumped by the heart, but the water would go on running at the tap in a continuous stream, just as the blood flows through the capillaries, and not in jerks.

These capillaries in the different tissues of the body run together and form little vessels which we call *veins.* These little vessels have very thin walls, not strong, with little muscular tissue in them; they run on together and form larger veins; these join one another, and so on. Now whereas in the arteries there were no valves at all after those valves just at the beginning of the great aorta, there are throughout the veins little flaps of membrane sticking out from their walls, and sticking out in such a way that blood can pass between them from the capillaries, but whenever any blood is forced back again towards the capillaries these flaps are so constructed that they close up the passage; so that the blood can only go one way in the veins, namely from the capillaries in the tissues of the body towards the heart.

These veins then go on running together, joining one another, continually forming larger veins; these larger veins end in two large veins called *venæ cavæ,* which means hollow veins. One comes from all the lower part of the body, and is called the vena cava inferior, and the other comes from the upper part of the body,

the head, the arms, etc., and is called the vena cava superior; these two large veins enter into the right auricle of the heart, having no valves at their entrance into it.

The blood that has been pumped from the left ventricle goes on therefore through the veins, passing the valves, until it gets by one or other of the two great veins into the right auricle of the heart; it goes on through the valves which we call the tricuspid valves, simply because there is no reason why it should not, they offer no resistance to it, and the ventricle is at the time empty, so the blood flows on into the right ventricle.

Before I go on I must mention that there is another vessel that enters into this right auricle, and that is the vein that brings back the blood from the substance of the heart. The two coronary arteries which go into the walls of the heart end in capillaries which form veins, ultimately joining in the coronary vein, which enters the right auricle by itself, and is protected by a valve.

So that where the large veins open into the auricle there are no valves, and the blood flows on through the auricle into the ventricle and gradually fills it; when it has got nearly full, the walls of the auricle, which are muscular walls though very thin, contract upon the remainder of the blood in the auricle and press it equally in all directions, against the blood in the veins to a certain extent, because there are no valves at the entrance of the veins, and on past the tricuspid valves into the ventricle, filling the latter and floating up the valves.

As soon as that happens the walls of the right ventricle contract, which is just what happened on the left side, thus pressing the blood against the valves, which are at the beginning of the large artery that leaves the right ventricle (which is, as I have already explained, the artery that goes to the lungs, called the pulmonary artery), and opening them, so the blood is forced out of the right ventricle into this pulmonary artery, and then takes place exactly what has been before described; the artery is bulged out when the blood is forced into it; it recoils and forces it against the valves, and shuts them, and so forces the blood on through the branches of the pulmonary artery, which divides into two, one to the right, and one to the left lung; in the lungs they subdivide into smaller arteries, and ultimately end in capillary vessels in the same way as the arteries do in the tissues of the rest of the body; those capillary vessels run together and form veins; these veins run on, and form four large veins, two for each lung, which, leaving the lungs, go into the left auricle of the heart; this left auricle of the heart is filled, and the blood flows from the left auricle through the bicuspid or mitral valve into the left ventricle, just in the same way as the blood flowed from the right auricle through the tricuspid valve into the right ventricle.

And now you see why it is called the circulation of the blood. You can start from one cavity of the heart, and follow the blood in its course right round, until you get into that cavity of the heart again, although the two sides of the heart do not communicate with one another

in any way except through this system of tubes. You can see already, from what has been described, that there are really two circulations; there is the circulation of blood from the left ventricle, through the aorta and its branches to the different tissues of the body, through the capillaries of those tissues into the veins, through the veins back again to the heart, viz. to the right auricle; that is called the *greater* circulation, or *systemic* circulation, because it is that of the general system. And there is the circulation from the right ventricle through the pulmonary artery and its branches, through the capillaries in the lungs into the veins of the lungs, which are called the pulmonary veins, and back to the heart again, viz. to the left auricle, and this is called the *lesser* or *pulmonary* circulation. The blood in the greater circulation starts from the left, and flows back to the right side of the heart, and that in the lesser, or pulmonary circulation, starts from the right, and flows back through the lungs to the left side of the heart.

There is much more blood in the greater than in the lesser circulation, and, on the other hand, the blood travels much faster in the lesser—about five times as fast.

Another thing that I wish to impress upon you is this; the blood leaving the heart by the great aorta travels at about the rate of a foot in a second, but when it gets into the capillaries, it travels at the rate of only an inch in a minute, so that it travels slower and slower the farther it goes; and the rate becomes more and more uniform.

You will, perhaps, have thought by this description that the contraction of the auricles and ventricles of the two sides of the heart follow one another like one, two, three, four, but this is not so. When the left ventricle is contracting, and driving the blood into the great aorta, at that same time the right ventricle is contracting and driving the blood into the lungs, so that the two are contracting at one and the same time. When the two ventricles have done contracting, and are resting or dilating, they are doing it at the same time. When the blood is running from those two great veins through the right auricle, and gradually filling the right ventricle, the blood is at the same time running from the lungs through the four pulmonary veins into the left auricle and from that into the left ventricle, so that the two sides of the heart are doing their work at the same time, the two auricles are filling at the same time, and contracting at the same time; the two ventricles are filling at the same time, and contracting at the same time.

The period of action, and the period of rest, are about equal, so that although the heart beats, say seventy times a minute, it has just that same amount of rest —half that minute it is contracting, and the other half it is at rest, and that is when the heart gets its rest.

When the ventricles of the heart contract they move the heart; this contraction causes a movement of the whole heart; the base of the heart is more or less fixed in its position by means of those great vessels that leave it; the apex of the heart, on the other hand, is free; when the walls of the ventricle contract, the apex of

the heart is tilted, and it butts against the chest-walls between the fifth and sixth ribs, thus causing what is known as the beating of the heart.

There are other physical signs produced by the action of the heart besides this beating, and these are certain sounds that the heart produces when it is in action—two sounds, called the first and second sounds of the heart.

The first sound is long and dull, and the second, which succeeds it immediately, is a short sharp sound; they are represented by the sounds produced in the pronunciation of the words *rub, dub,* the second one being said very sharply. These sounds can be heard by placing the ear against the chest-walls of a person.

The first sound probably has several causes; the most efficient cause is the action of contraction in the muscular walls of the ventricle; the second sound is certainly produced by the sharp closing of the semilunar valves, after the blood is forced into the arteries. After the blood has been forced into these arteries they recoil on it, and force it so sharply against those semilunar valves, that they come together with a click.

Now, it is by means of the alterations in these sounds of the heart that physicians are often able to tell whether there is heart disease, and to distinguish between various heart diseases.

I meant to point out to you that it is not necessary for the left ventricle of the heart to be strong enough, as was long thought, to force the blood, not only through the arteries, and through the capillaries of the tissues, but

also back again through the veins to the heart. You will see at once that this is not necessary, for you know that liquids always find their own level. If you had two vessels containing a liquid and communicating with one another, no matter what their size, the liquid would stand at the same height in both, and so it is with the blood-vessels in the body.

When the heart has driven the blood through the arteries, and through the capillaries, there is a column of blood in the arteries and capillaries supporting the blood in the veins up to the heart; and the fact that the veins are three times the size of the arteries does not make any difference; the height of the column of blood is the same. What the ventricle has to do is to force the blood through the arteries, and through the capillaries, and then the mere properties of a fluid will do the rest.

You will see at once that the ventricles have a great deal more to do than the auricles; the two ventricles have to drive the blood through considerable distances, and through an immense quantity of extremely fine tubes, with a great amount of resistance; the two auricles have nothing to do but to take the blood as it comes in by the veins, and let it run on through the valves, which offer no resistance, and just at the last to give a little squeeze; this is why the walls of the two auricles are very thin, and the walls of the two ventricles very thick, strong, and muscular. You will see at once, that as the left ventricle has to force the blood through the aorta, and all over the body, through

myriads of capillary vessels in all parts of the body, and at such distances, its walls must be very thick indeed, and they are much thicker than the walls of the right ventricle, which has not to force the blood nearly so far.

There is a remarkable exception to all this. The blood that goes from the great aorta or great artery to certain organs in the abdomen, viz., to the stomach, to the intestines, to the pancreas or sweetbread, and to the spleen, goes from the great artery of the body by means of small arteries, just as the blood that goes to the hands or feet does, and flows in capillaries in the walls of those organs. These capillaries run together, and form veins just in the same way as the capillaries in the hands or feet do, but these veins do not go into the great vena cava inferior, into which all the rest of the blood from the lower part of the body goes; they run together, and form one large vein, which goes by the name of the *portal* vein; this does not go straight into the vena cava inferior, but does a very remarkable thing; it goes into the liver, and in the liver it divides up into branches, like an artery. It is the only large vein in the body which does any such thing; it goes into the liver together with the proper artery of the liver, which also divides up into branches, and these two sets of branches run together and end in one and the same set of capillaries.

These capillaries run together and form a large vein, which leaves the liver, and runs into the vena cava inferior. That circulation of the blood from the stomach, intestines, pancreas, and spleen, through the liver, goes

by the name of the portal circulation. One of the most remarkable things in the bodies of animals is this large vein, which divides like an artery.

Remember that an artery is a vessel in which blood is going *from* the heart; a vein is a vessel in which blood is going *towards* the heart.

What is the shortest course that a particle of blood can take in the human body? A good many of you might probably say it is to go through the lesser circulation from the right ventricle through the lungs, and to the left auricle, but no, it is not so by any means; the shortest course is to go from the left ventricle of the heart, then through one of those little arteries that go into the heart itself, into the capillary vessels in the walls of the heart, through these capillary vessels into the veins of the walls of the heart, and through the veins into the little vein, which empties from the walls of the heart into the right auricle; that is a part of the greater circulation, but is entirely confined to the walls of the heart.

The course that a particle of blood must take in the human body so as to pass through the greatest length of capillaries is to go through the great aorta and into the capillary vessels of one of those special organs mentioned in the abdomen, *e.g.* the stomach, through the capillaries and into the veins of that organ, and so into the portal vein; through the branches of the portal vein in the liver into the capillaries of the liver, thence into the vein which leaves the liver to join the vena cava inferior, and so to the right auricle of the heart.

A few words about this fluid called the blood.

The blood is a fluid which consists of water containing certain substances in it. Some of these substances are suspended in it, as particles of chalk or of vermilion may be suspended in water, and some are dissolved in it just as salt or sugar can be dissolved in water.

In a hundred parts of blood there are twenty-one parts of solid matters to seventy-nine of water. Now the solid matters suspended in the blood are of very great importance, and the first important matters are the little bodies which we call corpuscles (meaning little bodies). These corpuscles are of two kinds, those that are more numerous are the red ones; they are little disc-shaped bodies of what may be called a semi-solid substance, of the consistency of jelly; they are just like little gun pellets, rounded at the edges, and compressed in the centre. These red corpuscles are the things which give the blood its colour. The liquid part of the blood is not red at all, but is of a pale straw colour, almost colourless. There are so many red corpuscles in it that it is just like a little water with a lot of powdered vermilion in it; the water itself is not red, but the vermilion is red, and so it is with the blood, the corpuscles are red, the liquid part is colourless.

Now you must fancy from that that there must be a great many of them, and that they must be very small; they are about the 3200th part of an inch across; 3200 would lie along an inch. That, however,

does not give you much idea of their size. I will give you a better idea, not so much of their size as of the number of them that are in the blood. Suppose I take a cubic inch of blood, how many do you think there would be in it? there would be seventy thousand millions—that seems very astonishing, but still it does not give you the least idea how many there are. I will give you an idea in this way. Suppose that you were to begin counting, and go on day and night without any intermission, and that you were to count one hundred a minute, it would take you, making allowance for leap years, just 1331 years to count the red corpuscles in one cubic inch of blood; so that if William the Conqueror had begun counting when he came over to England, and had gone on day and night at that rate, he would not now have got through two-thirds of the number contained in a cubic inch of blood.

Besides these there is another lot of corpuscles called white corpuscles, which are larger than the red corpuscles, and are irregular in shape; they have a peculiarity in that they have one or more smaller bodies inside them, and I may tell you that it is generally believed that the red ones are developed from these small bodies that are inside the white ones. They are not nearly so numerous as the red corpuscles, but in the proportion of something like three or four to 1000 red ones. Where they come from we shall see hereafter.

The blood when it is run out of the blood-vessels does not remain liquid, but a thick *clot* forms in it; this is called *coagulation* of the blood; the importance of

it to us is that when cut or abraded surfaces bleed, clots form, and plug up the cut ends of the capillary vessels, so helping to stop the bleeding.

There is another set of vessels in the body besides the blood-vessels, and these vessels do not form a closed circulatory system of tubes like the blood-vessels. They begin almost everywhere in the tissues of the body as thin fine vessels, and they run together into solid-looking bodies that are called glands. These vessels contain a fluid called *lymph*, because it is like water, and the vessels themselves, because they contain this fluid, are called *lymphatic vessels*, and the glands *lymphatic glands*.

These glands are more numerous in some parts of the body than in others; there are a great many about the intestines, and a good many in the neck and under the arms. The lymphatic vessels empty into cavities in the glands, and then other rather larger vessels start away from the other side of these bodies, and run on until they come to some more of them, and so these glands are joined together by the lymphatic vessels running from one to the other. They are like veins in that they have valves in them, which only allow the fluid to go one way, viz. from the smaller vessels towards the larger ones. The lymphatics from the lower part of the body all run together into a receptacle placed against the bodies of the lumbar vertebræ. This receptacle goes by the name of the *receptacle of the chyle;* it is connected with a tube about the size of a goose quill running up close to the left side of the bodies of the dorsal

vertebræ into the neck, and emptying itself into the junction of the vein from the left arm and the great vein from the left side of the head (called the jugular vein), and where it empties itself into the veins there is a valve, which is so arranged that no blood can go out of the veins into this tube, which is called the *thoracic duct*, but the fluid that is in that duct can go into the blood that is in the veins—that is the course of the lymphatic vessels of the lower part of the body, and of the left side of the chest and head and left arm. But the lymphatics of the right arm and right side of the head and neck, and the upper part of the right side of the chest, do not go into the thoracic duct at all, but empty themselves into the veins in a corresponding place on the other side; so that ultimately all the lymph that comes from all the tissues of the body gets into the great veins which run into the upper vena cava, and so into the right auricle of the heart.

Now the lymphatics of the small intestines have, especially after the digestion of food, a fluid in them which is not like water; but, on the contrary, it is white like milk, and for the same reason that milk is white, namely, that it has a great quantity of fat suspended in it; this white fluid goes by the name of *chyle*, and the lymphatics of the small intestines, because they contain this milky fluid, are called the *lacteals*, though they do not differ from the lymphatics in any other part of the body, except that they contain this white chyle, and they of course go through a series of glands into the receptacle of chyle, and so the old anatomists called

that vessel the receptacle of the chyle, although it also receives the lymph from the greater part of the body.

The lymph in the lymphatic vessels is a watery fluid containing a certain small quantity of solid matter in solution; the chyle is a milky fluid something like lymph, only containing a large quantity of fat in suspension, and rather more solid matter in solution, and both of these fluids, like the blood, are capable of forming clots under certain circumstances. Both in the lymph and in the chyle there are corpuscles exactly like the white corpuscles of the blood, and these two fluids are continually going into the blood, so that there is no doubt that the white corpuscles in the blood are identical with the white corpuscles in the lymph and chyle. There is very little doubt that the lymphatic glands through which these fluids go, together with some other bodies about which I shall speak farther on, have the manufacture of the white corpuscles of the blood for their office.

Before leaving this, let us consider of what the blood in the right side of the heart consists, and where it comes from. I have described all the places that it comes from but one, and I will tell you of that one as we go on. This is the blood that goes into the right auricle of the heart, through the two great veins, from all the parts of the body. Suppose we take these two veins one at a time. The blood that comes in by the vena cava inferior is the blood from the lower part of the body. It contains the blood that has gone through the portal circulation in the liver, and has undergone very remarkable changes. Most of this blood has come

from the digestive organs. It contains also the blood not yet mentioned, viz. that which comes from the kidneys, which has undergone certain important changes in the kidneys. That is what the inferior vena cava brings into the heart. The superior vena cava brings the blood from the upper part of the body, the lymph that has come in by the thoracic duct on the left side, and lymphatic ducts on the right side, and the chyle which has come from the lacteals through the thoracic duct. So you see that the right side of the heart contains a very curious and complex mixture.

LECTURE III.

RESPIRATION.

WE will now consider the apparatus by means of which we breathe, the way in which that apparatus works, and the result of that working.

The principal organs that are used in breathing go by the name of the *respiratory tract.* This begins with the nostrils, passes along through the lower part of the cavities of the nose, on each side of the partition or *septum*, as it is called, over the hard and soft palate of the mouth, into a cavity which we call the *pharynx*, situated behind the mouth, opening into this cavity by two apertures called the posterior nostrils; then it passes on through the pharynx, down into a box made of cartilage or gristle in the front of the throat, which we call the *larynx*, and in which box the voice is formed; it passes through an opening in that box, called the *glottis*, between two cords, called the *vocal cords*, into the *trachea* or *windpipe*, which lies in the front part of the neck. Now the windpipe is a tube which must be always open; it would not do if the windpipe were closed, even for a short time, for reasons that we shall soon see, and so its walls are provided with incomplete rings of cartilage or gristle, something like the letter C, the ends being joined by membrane which forms the back part

of the windpipe, where it touches the gullet, down which the food passes, and these rings being not complete, but joined by membrane, offer little or no resistance to food passing down the gullet. This windpipe passes down the front of the neck, into the thorax or chest, and there divides into two branches, still with rings. These two branches go by the name of the *bronchi*. You will remember the name, because it is from this name that the word bronchitis comes; bronchitis being inflammation of the lining membrane of these tubes, and each of these tubes is called a *bronchus;* these bronchi go one to each lung, the lungs being two organs, situated one on each side of the cavity of the thorax or chest. When each bronchus gets into the lung, after going a little distance in the structure of the lung, it divides into a great number of branches. Now inside the lung the rings do not remain, but the tubes require to be still wide open, and so in their walls there are patches of cartilage sufficiently stiff to keep the tubes open. At last they become very fine, and the stiff cartilage is lost, but there is a certain amount of muscular fibre in their walls; then each of these fine tubes has at its extremity a large number of small bags or sacs made of very elastic membrane sticking out from its walls; these are called the air-sacs of the lungs, and are about one-fortieth of an inch in diameter.

All this system of tubes, beginning with the nose and going down to the fine bronchi, is of course lined with a form of the internal skin, because it is a system of tubes communicating with the external air.

The peculiar character of the epithelial lining of the mucous membrane of the respiratory passages is that it has on its surface an enormous number of very fine hair-like bodies, called *ciliæ*, which have a property of their own of continually moving, lashing towards the outlet of the respiratory passages in the nose, and it is by the movement of these little ciliæ that the respiratory passages do not get clogged up with the moist secretion of the mucous membrane.

Such is a brief description of the air-passages of the lungs.

You will remember I told you that the pulmonary artery which leaves the right ventricle of the heart divides into two branches, one of which goes to each lung, and then subdivides into a very large number of branches, ending at last in very fine capillary vessels —just in the same way as the branches of the large artery of the body end in capillaries in tissues of the body—which entwine themselves round the little air-sacs of the lungs, and which are so near together, that the capillaries generally have an air-sac on each side of them; the capillaries then run together and form little veins. These little veins join and form larger veins, which ultimately unite in two large veins for each lung, the pulmonary veins, and these run into the left auricle, the upper chamber of the left side of the heart.

The chief things that we have to consider in the lungs are the air-passages and the blood-vessels.

Now the lungs are contained in the cavity which we call the thorax or chest. Before we can understand

how the lungs work, and what they do, we must understand the cavity in which they are contained, and the movements of the walls of that cavity. This cavity has the root of the neck at its upper part; the spinal column and back part of the ribs behind; the ribs, and the things which connect the ribs at its sides, and partly in front; the breast-bone and the cartilages of the ribs, and the structures connecting them in front, and the partition mentioned in the first chapter as being between the thorax or chest and the abdomen, which we called the diaphragm, below; this partition is partly muscular, and partly tendinous; it rises by muscular fibres from the bodies of the lumbar vertebræ; these go by the name of the pillars of the diaphragm; they run upwards from the bodies of the vertebræ in an arched way, and are attached to the edges of the lower ribs and the cartilages in front, and to the lower part of the breast-bone, so that the diaphragm forms a complete partition between the thorax or chest and the abdomen.

I have mentioned that there are structures between the ribs; the ribs are connected partly by fibrous tissue, and more particularly there are muscles that pass between the ribs, from one rib to the next, and there are two important layers of muscles that pass between the ribs that are of great use in respiration; these muscles, because they run between the ribs, go by the name of *intercostal.* The outside ones are called the external intercostal muscles, and their fibres run from each rib downwards and *forwards* to the rib below it; the inner ones are called the internal inter-

costal muscles, and their fibres run downwards and *backwards* from each rib to the one below it.

The chest cavity is entirely enclosed by these walls, and is completely shut off by them from the external air, so that there is no communication between the external air and the cavity of the chest itself. The chest is filled by the organs that it contains—these organs I have mentioned before, the heart and the lungs. As the heart is surrounded by a serous bag, so each lung is surrounded, except at the place which is called its root, which is where the bronchus and the pulmonary artery enter it, and the pulmonary veins leave it, by a serous bag. One layer of this serous bag is against the lung, and the other layer is against the chest-wall; this serous bag is called the *pleura*.

That is a rough description of the organs of breathing, and the walls of the cavity in which they are.

How does this contrivance work? In the first place, the walls of this cavity, the chest, are movable; the diaphragm is for the most part muscle, and we know that muscles are capable of moving by contracting; the sides and part of the back, and part of the front of the chest are movable, the walls as a whole are movable, because the ribs are attached by true joints to the spinal column; so that the whole set of ribs and the structures which join them and the breast-bone can be moved as a whole upon the spinal column.

Now suppose the diaphragm to contract, what would happen? the muscular fibres of the diaphragm lie in a curved line; if these fibres contract, they become shorter;

if they become shorter, the distance that the fibres run must be less; they must approach more nearly to a straight line between the two points, so that when the muscular fibres of the diaphragm contract, the diaphragm as a whole becomes flatter, and so the chest cavity is made longer from above downwards.

When the external intercostal muscles contract (remember that the fibres of these run from each rib downwards and *forwards* to the next rib) the distance between their points of attachment must be made less, and this results in the raising of the ribs, thus the ribs, by the contraction of the external intercostal muscles, are raised upon the vertebral column, and so the breastbone is raised and tilted forwards.

The chest is in this way made deeper from before backwards, and wider from side to side: so that by the contraction of the diaphragm the chest is made longer from above downwards; and by the contraction of the external layer of muscles between the ribs, the chest-walls are raised, and the chest is made deeper from before backwards, and broader from side to side. You might say at once, But, then, do these things happen at the same time? Of course it might so happen that when the diaphragm contracted these external muscles should not contract, but, on the contrary, other muscles might contract and make the chest cavity smaller in other directions. But the answer is this, that when the diaphragm contracts and makes the chest cavity deeper from above downwards, at the same time the external layer of muscles between the ribs contracts and makes

the chest wider in the other dimensions, so that the chest cavity is at the same time made larger in all directions.

Now the result is that, by lifting the chest-walls away from the lungs, a certain amount of pressure has been taken off the lungs, while the pressure inside remains the same, and so is sufficient to expand the little air-sacs, and thus to inflate the lungs, until they are sufficiently large to fill the enlarged cavity of the chest; this process is called *inspiration*, or breathing in.

It is not the pressure of air inside the lungs that pushes the chest-walls out.

When we inspire, the chest-walls are lifted away from the contents of the chest, and the cavity of the chest is made larger. The diaphragm contracts and makes it larger in one direction; the external muscles between the ribs make it larger in the other directions, so that it is the chest cavity that is made larger first, and then, as that cavity is not connected with the external air, the air must come in through the tubes that lead into the lungs, and makes them larger so as to fill the enlarged cavity, and they are made larger because they are capable of being extended, consisting, as they do for the most part, of little exceedingly elastic bags.

Then when this has been done, *i.e.*, when inspiration has taken place, the next thing that happens is that these little elastic air-bags begin to collapse, because when the diaphragm and the external intercostal muscles stop contracting, the pressure of the external air upon the walls of the chest is no longer resisted by the contraction of the muscles, so the external air presses upon the walls

of the chest and its contents, and gradually brings them back to the original position. The instant that begins, these little elastic air-sacs partly collapse and squeeze the air out of them; at the same time the internal intercostal muscles, the fibres of which run in the opposite direction to those of the external ones, begin to contract and help the external air which is pressing upon the ribs by pulling them back towards their former position. This is called *expiration*, and thus about as much air is driven out of the lungs as was drawn in during inspiration.

So you see the chief forces at work in inspiration are active muscular forces, by which the chest cavity is made larger, and the chief agents in expiration are passive agents, the pressure of the air upon the walls of the chest and abdomen (because the pressure of the air upon the walls of the abdomen push it back and help the diaphragm into its position), one passive force, and the elastic recoil of the air-sacs, another passive force, and these forces are aided, and that is all, by the contraction of the internal muscles between the ribs, which help to bring the ribs down again.

This, then, is how the lungs are inflated, how the lungs collapse, and how the chest cavity is reduced to its original size.

We have seen roughly now what the apparatus is, and how it works.

An adult in breathing air in, inspires on an average from 20 to 30 cubic inches of air, that is to say about three-quarters of a pint; and he breathes out the same quantity.

This air is called *tidal* air, because it is continually flowing in and out. He can breathe out, if he expires as hard as he is able, about 100 cubic inches more, and besides that there still remain in the lungs another 100 cubic inches, which he can never breathe out, so that the lungs always contain some air, and this air that remains in the lungs, and is never got rid of, goes by the name of the *residual* air. The whole quantity, from 220 to 230 cubic inches, goes by the name of the *vital capacity* of the lungs, and varies in different persons, and in the same persons at different times of life, and in disease.

Besides that, a person can draw in, by a deep inspiration, about another 100 cubic inches of air.

Let us consider what happens to the air that is drawn in, and what happens to the blood that is in the lungs.

If we examine the air that goes into the lungs, we find that it consists of three gases, with a certain variable quantity of watery vapour dissolved in it (because air will dissolve water very much in the same way as water will dissolve sugar or salt). The air that goes in consists of three gases chiefly. It contains nitrogen, about 79 parts in 100; it contains a gas which we call oxygen, very nearly 21 parts in 100. But you say that makes up the 100 parts—remember I said "nearly 21 parts of oxygen." And it contains another gas called carbonic acid, to the extent of about 4 parts in 10,000. I will give you the exact composition in a future Lecture.

So the air consists of nearly 4-5ths nitrogen, more than 1-5th oxygen, and a trace of carbonic acid.

This is the air that is drawn into the lungs. Now what air comes out of the lungs, and what does it contain?

We find that, however much or little water the air contains when drawn into the lungs, the air that comes out of the lungs is always saturated with moisture, so that we see that a great deal of moisture is continually got rid of from the lungs. We find further, that whether the air that we take in is cold or hot, the air we breathe out is always very nearly as hot as the blood; so that a considerable quantity of heat is lost from the body by means of the lungs. Then we find that the air that we breathe out contains just about as much nitrogen as we breathe in, so that in the lungs very little change takes place with regard to the nitrogen that is breathed. We find, on the other hand, that about 5 per cent has been lost, and that that loss has been oxygen. Of every 100 parts of air that we breathe in very nearly 5 per cent is lost, and that 5 per cent consists of oxygen. Whereas the air we breathe in contains nearly 21 parts, the air we breathe out contains only about 16 parts, or a little more, and the place of that is supplied by carbonic acid, so that the air we breathe out contains, at any rate, more than 4 per cent of carbonic acid.

You will see I have mentioned 5 per cent in the case of oxygen as lost, and 4 per cent in the case of carbonic acid, which takes its place; I have done this in order to fix in your minds the fact that rather more oxygen is absorbed in the lungs than carbonic acid given out. So that while the air contained only 4 parts in 10,000 of carbonic acid, the air that we breathe out con-

tains at least 4 parts in 100, or at least 100 times as much carbonic acid as the air that we breathe in. Besides that, the air that we breathe out contains a certain quantity of foul organic matter, and this it is that renders the air of rooms which has been breathed over and over again injurious; this it is that chiefly tends to render the air of crowded rooms disagreeable, and this stuffiness of the air is a certain sign, and has been shown to be a very accurate index, of the state of the impurity of the air.

Now before I go on to consider the changes in the blood, I must point out that air that has been breathed once is not fit to breathe again, and this for several reasons.

I suppose if I were to ask you what it was that caused this unfitness, your answer would be because it contains a large quantity of carbonic acid. That is not the first reason—the first reason is because it contains a large quantity of foul organic matter; other reasons are because the amount of oxygen in the air has been seriously diminished, and because its carbonic acid has been increased. The quantity of carbonic acid is not the most important thing, but we shall say more on that farther on.

Now, then, what happens to the blood as it goes through the lungs? The mixture of blood which comes into the right auricle of the heart is pumped by the right ventricle through the pulmonary artery into the lungs; that blood is what we call the venous blood; it is of a dark purple colour, so dark that it is commonly called black blood. We call it venous

blood, because it is the kind of blood that is contained in the large veins in the body. You will remember the blood of the right side of the heart comes from the body by the large veins (venæ cavæ), that is why it is called venous blood. This black blood is pumped through the pulmonary artery and its branches into the capillaries of the lungs. Through these little capillary vessels, situated upon the walls of the air-sacs, the blood passes into the pulmonary veins, and runs through the pulmonary veins into the left auricle. When it has passed through these little capillary vessels it is no longer venous blood; it has become bright red blood, which we call arterial blood; this comes back to the left auricle of the heart, and from that into the left ventricle, and is pumped by means of that left ventricle through the arteries of the body, and that is why we call it arterial blood.

I told you, in the last Lecture, that blood contained substances in suspension, as well as in solution, and I mentioned some of these to you; but I did not tell you that blood has a property of dissolving the gases of the air, and blood contains dissolved in it the gases of the air, not, however, in the proportions in which they exist in the air, but in the proportions in which they are capable of dissolving in blood, and combining with certain substances in the blood. It contains a large quantity of carbonic acid, a considerable quantity of oxygen, and some nitrogen dissolved. We have already said, that in the lungs the blood gains oxygen and loses carbonic acid. The oxygen, which has been gained by the blood, gets into it from the air in the air-sacs, and

the carbonic acid and moisture, which the expired air contains, come from the venous blood in the capillary vessels into the air in those air-sacs. It is a fact that moist membranes have the property of allowing substances in solution to pass through them, whether they are solids in solution or gases, and these substances in solution pass through moist membranes according to definite laws and at definite rates.

Now, we say, then, that by passing through these capillary vessels, the blood has gained oxygen from the air, and has given up carbonic acid and water into the air; by these changes the blood becomes bright red—that is a thing ascertained by experiment. If you take dark venous blood, and put it in a bottle and shake it up with oxygen gas, it becomes bright scarlet, or arterial blood; and, on the other hand, if you take the bright scarlet blood, and shake it up in a bottle with carbonic acid, it becomes dark venous blood. There is no doubt that the change in the colour which takes place in the lungs is a change caused by getting rid of carbonic acid and gaining oxygen. It goes through these capillary vessels of the lungs which lie upon the air-sacs, and these are moist membranes, so you see that by this contrivance the black blood in the branches of the pulmonary artery is brought into contact with the largest possible quantity of air in an immense number of small sacs of moist membrane at the ends of tubes, which are in communication with the external air. This blood has too much carbonic acid and too much water. Some of the water passes through the membranes into

the air in these air-sacs; some of the carbonic acid goes out from the blood into the air in these air-sacs; and some of the oxygen of the air in these air-sacs goes in to take the place of the carbonic acid, and so the blood goes on with less carbonic acid, less water, and more oxygen. This extra carbonic acid, and the extra water that are got rid of in the lungs, where do they come from? The arterial blood which has been pumped by the left ventricle of the heart into the different tissues of the body, runs through the capillary vessels of those tissues, so that there you have this arterial blood running in an immense number of fine streams through these fine capillary vessels, made of moist membrane, in the different tissues of the body; an interchange takes place between the contents of those capillary vessels and the juices in the tissues of the body; the blood gives up substances which the tissues require to nourish them, and some substances go back from the juices of the tissues into the blood, substances which the tissues have done with. The surplus of all this is picked up by the lymphatic vessels.

The result is that, when the blood has gone through any tissue in the capillary vessels, it comes out through these capillary vessels into the little veins as black venous blood, and it is this change of the blood from the bright arterial blood which is supplied to the tissues of the body into black venous blood that is reversed in the lungs.

What becomes of the oxygen that is absorbed from the air into the blood?

This oxygen gas is found to be dissolved in the blood to a much greater extent than it would be dissolved in water. Blood is capable of holding more oxygen than water, and it is found that this oxygen gas attaches itself to the little red corpuscles in the blood. One of the uses, at any rate, of these little red bodies in the blood would appear, then, to be to carry the oxygen about. The oxygen finds in the blood certain substances with which it can combine, substances partly derived from the food and partly waste substances that have got into the blood; it combines with those substances, and two of the results of that combination are two substances that I have already mentioned as being got rid of from the lungs, water, and carbonic acid. It is by means of this combination of the oxygen with the substances that it finds in the blood that our animal heat is kept up. Whenever things combine together to form other substances, heat is given out, and it is by this combination of oxygen that we breathe in with substances that it finds in the blood that the heat which we call animal heat is produced, and that the temperature of our bodies is kept up. The temperature of the blood must be kept up to within a few degrees of the ordinary standard, or else we could not exist.

Respiration takes place at various rates during different periods of life. The young child respires very much faster than the adult. An adult respires fifteen or sixteen times in a minute, but the activity of respiration, and so the activity of all those changes that are produced by respiration, and the amount of the puri-

fication of the blood that can be produced by respiration, may be increased in various ways.

Exercise is one great agent in increasing the activity of respiration. It is also increased by cold. We always respire more quickly in cold weather, and you can see why. It is because in cold weather we lose heat faster, and so require to make more heat to keep ourselves sufficiently warm.

The first use then of the respiratory apparatus is to supply oxygen to burn substances in the blood, for this combination is a kind of burning, and so to produce the animal heat upon which our lives depend, which is converted into all the forces which we exert, whether muscular or mental.

All the forces of our life are derived from the animal heat produced in the way just described—viz. by burning the different substances in the blood with oxygen gas. I use the word burning advisedly, because it is precisely the same kind of process that we use for all our methods of lighting and warming, as they all consist of taking substances capable of combining with the oxygen of the air, and making them combine with it, as in burning coal, gas, or candles.

And another important use of this apparatus is to get rid of certain substances from the blood which are superfluous in it, and which are injurious to the system, thereby helping to purify the blood, so that it may be of a proper quality to nourish the different tissues of the body.

LECTURE IV.

NUTRITION.

The food that we eat requires to be prepared in various ways before it can become part of the structures of which our body is composed. To this end, there is a complex apparatus contained in our bodies, and there are certain liquids provided in connection with this apparatus, and certain organs in which these liquids are made, and thereby the food that we take is reduced to a condition in which it can be assimilated to the structures of our own bodies. This apparatus we call the *digestive apparatus;* and this apparatus and its working I am now going to describe.

The digestive apparatus begins, as before mentioned, with the mouth. The mouth is a cavity, the walls of which are partly bony and partly muscular and fibrous; the upper part of it, the roof, is what we call the palate, the front part of which is bony, and the back part muscular and fibrous; there is then the hard palate and the soft palate; the side walls of the cavity of the mouth are the cheeks, which are for the most part muscular, and which are capable of being moved in various ways; and just inside the cheeks are the jaws. At the floor, we have a large organ, which we call the

tongue, which is almost entirely muscular, composed of several layers of muscles, layers which run in different directions, so that the tongue is capable of a great variety of movements. At the front of the mouth we have the lips, forming a valve, and an opening to the external air; at the back of the mouth is an opening communicating with another cavity, called the pharynx.

These are the boundaries of the cavity of the mouth, and the beginning of the digestive apparatus.

In the first place, in this cavity we notice that the edges of the jaws are provided with a special set of instruments, the *teeth*—instruments for cutting, tearing, and grinding the food. These instruments are fixed into the jaw-bones, just as nails are fixed into a board.

The whole of the cavity of the mouth is lined, and the whole of the digestive apparatus is lined, by a membrane, which is continuous with the external skin of the body. You will remember I have mentioned in a previous Lecture that the membrane which lines the different cavities of the body communicating with the external air is called the mucous membrane, and so the mouth, and the rest of the digestive cavity, are lined with mucous membrane.

This mucous membrane around the edges of the jaws, into which the teeth are implanted, becomes harder and more firm than it is in other places, and goes by the name of the gums; it is continued right down into the holes in which the teeth are implanted, and over the parts of the teeth which are implanted in the jaws, and which we call the roots of the teeth, so that the teeth

are not merely fixed in the jaws by their roots, but the holes, or sockets, in the jaws, and the roots of the teeth, are lined by a firm, tough membrane. This renders their position in the jaws more secure than it would otherwise be.

The teeth are of several kinds, but all have certain characters in common. In the first place, the part projecting above the gums is called the crown of the tooth; below this, at the attachment of the gum, is the neck of the tooth; then the teeth have processes below projecting into holes in the jaws—these processes are called roots, or fangs, and each tooth has one or more of these processes; besides this, every tooth has a cavity in its interior which is continued down right through the root or roots of the tooth, so that at the end of each root or roots there is a perforation leading into this cavity, and it is through those holes or perforations that the blood-vessels and nerves pass into the teeth. You will see from this that the teeth, just like the bones, form part of the living structure of the body, and change just like any other part of the body, only not at the same rate. The bulk of each tooth is made up of a substance, which is only found in teeth, which goes by the name of *dentine*, a substance harder than bone; for, whereas bone contains about one-third of organic matter and two-thirds of inorganic or mineral matter, dentine contains only a quarter of organic matter and three-quarters of mineral matter. Around the fangs of the teeth there is placed a small quantity of a substance called *cement*, almost exactly resembling bone; and upon

the crown there is a substance which covers the whole of it above the gum, which is the hardest and most indestructible substance in the human body, and goes by the name of *enamel*; it consists almost entirely of inorganic or mineral matter.

You can now see from the structure of the teeth how very important it is that the crown of the tooth should not be broken, injured, dissolved, or decayed in any way. The enamel on the crown of the tooth is extremely hard, and especially fitted for the purposes for which the teeth are used. It is not a very thick layer, and if broken by biting hard substances, or decayed by want of attention to the cleansing of that part of the tooth which is above the gum, then the dentine is exposed and it is quickly destroyed; for if the enamel, which is harder than that, is not sufficient for your purpose, the dentine cannot be. When the dentine begins to go it goes very fast indeed, and the teeth decay into the cavity in the interior of the tooth; that is how the nerve gets exposed, and we get those pains which are familiar to most of us. You can see, then, from the construction of the teeth what an important thing it is to take care of them. Now, these are the things which are common to all teeth. But teeth are of different kinds, and there are two sets of teeth; there is the first set of teeth, which we call the milk teeth; they are also called the temporary teeth, because they are teeth which we only retain for a small portion of our lives; and there is another set, which we call the second or permanent set of teeth.

As the teeth of the two jaws are sufficiently alike,

and those on each side of each jaw are alike, I will describe the teeth on one side of one jaw.

Now, as to the first set of teeth. In front there are two teeth with edges like a chisel, cutting edges; these are called the *incisor* teeth, because they are used in cutting up the food, and they are especially developed in animals which have to eat hard foods. There is a certain class of animals which go by the name of rodents or gnawing animals, some of which we know very well, such as hares, rabbits, squirrels, rats, mice, etc., and these all have the front or cutting teeth very remarkably developed. Then, behind these two, there comes a tooth which is pointed; it has no cutting edge like the first two; and because it is the tooth that corresponds to the tooth which is most easily seen in a dog's mouth, it goes by the name of the *canine* tooth, although in us it projects little beyond the rest of the teeth. The function of this tooth is to tear the food, and these teeth are most developed in carnivorous animals, such as the lion, the bear, the dog, and the cat. Behind this tooth there come two teeth which have large square surfaces with points upon them, and they are especially adapted for grinding the food, and so go by the name of *molar* teeth, because they, more or less, resemble mill-stones in their action. These teeth are especially developed in animals which eat food which requires grinding, such as the horse, the cow, sheep, etc. They are developed sometimes almost to the exclusion of the rest of the teeth.

These just described belong to the first set or milk

teeth, and they are the temporary teeth. Of these there are *five* teeth on each side of each jaw; *twenty* in all.

These teeth are replaced at about five years of age in the following way: the two incisor or cutting teeth are replaced by incisor or cutting teeth; the canine is replaced by a canine stronger and larger, but still a canine tooth; the two molars are replaced by two teeth which have not one point like canines, but two points on their summits, and so go by the name of *bicuspid.* The canines have only one root, the bicuspid have really one root, but it is divided into two at the point. Then, besides these, there are three more molars developed. In the adult there are on each side of each jaw two incisor or cutting teeth, one canine or tearing tooth, two bicuspids, which have replaced the molars of the infant, which are partly tearing and partly grinding teeth—being in construction between the canine or tearing and the molars or grinding teeth—and three true molars. There are then in a complete set eight teeth on each side, making thirty-two in all. The last molar, on each side of each jaw, is developed at a late period of life, and they commonly go by the name of the wisdom teeth.

You will probably think it strange that in human beings the teeth should be of different kinds, although almost all of the same length; but this is sufficient to show us that human beings are adapted to eat various kinds of food. Man is not like the animals,—as horses, cows, sheep, etc.—which live only on vegetable foods, nor like lions, tigers, etc., which eat animal food only.

Animals that live on one kind of food have their teeth developed in the way which best enables them to eat that particular kind of food, but we, as you see, have teeth corresponding to the teeth of various classes of animals; so it is quite clear, from the mere construction of our mouths, that we are adapted to live upon various kinds of food.

I said the mouth was lined by a mucous membrane; in this mucous membrance there are very numerous depressions; these form what we call *glands*, and, because they are in the mouth, they go by the name of buccal glands; and here I may take the opportunity of saying, that when I speak of a gland, that is what I mean—I mean a depression from the skin, or from the mucous membrane.

You will remember, when speaking about lymphatic glands, I told you that they were not glands properly so called, and when speaking of a true gland, a depression from the skin or mucous membrane is meant.

It does not matter how blunt that depression may be, how far it may go, or how far it is pushed out in different directions. These buccal glands are merely little depressions.

But, besides, there are six important glands, three on each side, connected with the mouth; these secrete fluid, which is poured in the mouth, and goes by the name of saliva or spittle. These six glands secrete fluid, which, together with the fluids secreted by the numerous little glands I have mentioned before, has extremely important purposes.

When we take food into our mouths it is subjected to certain processes in the mouth, which altogether go by the name of mastication and insalivation (or mixing with the saliva). This is done by means of the movement of the lower jaw upon the upper jaw (because the lower jaw alone is movable, moving up and down, across, forwards, and backwards), the movements of the tongue, and the movements of the cheeks. While the lower jaw is moving, so as to crush the food between the teeth, the tongue and cheeks act in opposite directions, so as to keep the pieces of food between the teeth. When the food gets on one side, either the tongue or the cheeks contract, and push it between the teeth again; so that, by a series of extremely complex actions, the food that we have in our mouth is kept, while necessary, between the teeth, and so divided into very minute fragments. You will see how this acts, and the way in which the food is kept between the teeth, when you consider how frequently, when eating game, you find a shot in your mouth, and you feel it half a dozen times between your teeth before you can secure it, thus showing the extremely perfect way in which the muscles of the cheeks and the tongue act to keep the particles of food between the teeth, so as to ensure their being completely crushed. While this is going on, and because this is going on, the glands that I have mentioned are secreting their fluids; the very fact that the tongue and cheeks are moving, is sufficient to make the salivary glands secrete their fluids, and they secrete comparatively little fluid at any other

time, only just sufficient to keep the mouth moist. Whenever anything is in the mouth they are excited to secrete more fluid, as any of you who have been up a mountain can testify. The mouth then, or when going for a long walk, always becomes dry; and it is a very capital plan to keep a small pebble, a marble, or a plum-stone in the mouth, so as to secure, by continually moving it about, a constant flow of saliva.

So we see that the presence of the food in the mouth, and the exercise of the tongue and cheeks, cause the salivary fluid to flow from the glands into the mouth; that fluid is mixed up with the food that has been minutely subdivided by the teeth, the whole thing together forming a ball. The fluid, in the first place, moistens, and, in the second place, it aërates it, as of course there are bubbles of air in the saliva. This soft ball of food is gradually passed backwards to the hinder part of the mouth between the tongue and palate, and so it comes to the soft palate, and there the soft palate ordinarily hangs downwards; and as soon as the ball of food touches it, the muscles of which the soft palate is composed and the adjacent muscles tilt it upwards across the cavity behind the mouth, which is called the pharynx. You will see the importance of this; the soft palate, by being tilted upwards, and forming a roof to the pharynx, prevents the food from going upwards and backwards into the nose, and it prevents the fluid also from going into some other tubes, which I shall mention presently. The food then is, as you see, just at the entrance of the pharynx, the soft palate being

over it, and the root of the tongue being below it. When it gets to this place, the ball of food is seized by some muscular bands, which pass down from the soft palate towards the roof of the tongue on each side.

It is seized by these bands; there are two pairs of them, one on each side of each tonsil. You all know where the tonsils are, at the back of the mouth; at any rate, all who have suffered from quinsy know whereabouts the tonsils are. These muscular bands which run down on each side of the tonsils seize hold of the ball of food; at the same time the tongue rises a little upwards and backwards, and the root of the tongue presses down the epiglottis or lid of the larynx. Now you remember that over the larynx, or box in which the voice is formed, there is this cartilaginous lid called the epiglottis, because it is over the glottis, the glottis being the aperture leading into the larynx, and so into the windpipe. So we see that when the tongue rises backwards with the ball of food on it, it pushes down the epiglottis, and then the muscular columns contract upon the ball of food and push it over the lid of the larynx into the pharynx or cavity behind the mouth, and so into the continuation from the pharynx, which is called the gullet or swallow, and that is how the food is prevented from going the wrong way; however, food and liquids do sometimes go the wrong way when we are talking while we are swallowing. You can see exactly how it happens: when we are talking the air is coming out and that lid cannot be shut properly, and so some of the food gets into the larynx.

I want to make you understand what the pharynx is, by mentioning to you the different tubes which open into its cavity; no less than seven tubes lead into or out of it. I have mentioned all but two.

In the first place, the mouth leads into it; in the second place, the two cavities of the nose lead into it; and in the third place, two tubes, not mentioned before, forming part of the apparatus of hearing, called, from the name of their discoverer, the Eustachian tubes, lead into it. Then the windpipe is connected with it, and so is the gullet or swallow, and that makes the seven.

When the soft palate is raised up so as to prevent the food or drink from getting into the nose—and in all people who have cleft palates, until a particular operation is performed, some of the food goes back into the nose, and the same thing happens with people who have had their palates destroyed by disease—it also prevents the food from getting into the two Eustachian tubes, so the food gets into the gullet or swallow, called, in anatomical language, the *œsophagus.* This tube has soft, compressible walls; it is strong and fibrous, and has on its outside two muscular coats, and so it is capable of contracting. It has also a coat which carries blood-vessels to supply it with blood, and it has lastly, of course, a mucous membrane. It passes down through the neck, close in front of the bodies of the vertebræ, and close behind the windpipe, and you will remember I told you that the incomplete cartilaginous rings of the windpipe, which nearly surround it and keep it wide open, have their ends joined together at the back by

a fibrous membrane, and this membrane is closely attached to the fibrous coat of the œsophagus or gullet, and it is because that membrane is there that the windpipe does not offer any resistance to the food which is being swallowed.

The œsophagus then passes downwards through the neck and chest, and through a hole in the diaphragm into a bag that we call the stomach. As soon as the food gets from the pharynx and over the lid of the larynx into the œsophagus, the fibres of the œsophagus, which are round it and which are called circular fibres, contract upon the ball of food and hold it, and then the fibres running lengthwise down that part of the gullet contract and pull up the next bit of the gullet, the circular fibres of which at once contract upon the ball of food, so that the latter is continually caught hold of by each piece of gullet, and then by the next piece, and squeezed farther down. That action is peculiar to the whole of the intestinal canal, including the gullet, and goes by the name of the *peristaltic* action.

The food does not *fall* down this tube into the stomach, for the simple reason that the gullet is not wide open like the windpipe; each part is only open when the food is going down, and it is opened by the food, for as soon as it gets to one part, that part contracts upon it, and, as it were, squeezes it to the next, and so on; and this peristaltic action does not merely happen with food, but with drink also. When you take drink into your mouth and swallow it, it does not fall down the gullet; it is swallowed in precisely the same

manner as the solid food, and that is illustrated by the fact that when a horse drinks the drink cannot *fall* up his neck into his stomach, he swallows it up his neck. We need not go to horses; there are some persons who can stand on their heads, and drink while standing on their heads; it is a common feat of jugglers.

When a man drinks standing on his head, it is quite clear that the water does not fall up his neck; so that whether eating or drinking we deliberately swallow the thing almost in morsels, at any rate in portions.

While we are using our mouths we know what we are about, for all the apparatus connected with our mouths is a voluntary apparatus. The instant food has got into the pharynx and is going down the gullet, we have nothing whatever more to do with it; the movements which go on in the gullet are purely involuntary; we can only directly influence our action upon the food that is in our mouths—and that is a very important point to consider in this way—that it points out to us that these actions in our mouths, resulting in the subdivision of the food and its mixture with the saliva, are voluntary actions, and that we ought not to be doing anything else at the same time; our attention ought not to be occupied with other things while we are masticating the food in our mouths, or the result is, that the food is not sufficiently divided, not sufficiently mixed with the saliva, and therefore not properly digested, and if not properly digested it cannot be absorbed, and so does not conduce to the nourishment of the body.

I have told you that the food is mixed in the mouth

with the saliva. This exerts an important chemical action upon it in the following way. There is a great deal of cooked starch in our food. Now the saliva has the property of turning starch which cannot be absorbed into the blood at all, into a particular form of sugar, which is very readily absorbed into the blood. Besides having a mechanical use, the saliva has then also the chemical use of beginning the process of digestion, by changing one part of the food which is in a form in which it cannot be absorbed into the blood and into the body, into another form, namely a kind of sugar, which can most readily be absorbed into the body. This mixture of food and saliva passes down the gullet, in the way I have described, into the bag we call the stomach. Now, the stomach is situated across the upper part of the abdomen, rather more on the left side than on the right; the gullet or swallow comes into it nearly, but not quite, at its left end.

The coats of the stomach are similar to those of the gullet, only that the fibrous coating on the outside of the stomach is continuous with the serous bag which is wrapped about the outside of all the organs in the abdomen; that bag is called the *peritoneum*, because it is round about the intestines. You will understand what I mean, when I tell you that the bag is folded about outside of the organs, in a similar, though more complicated manner, to that in which the serous bag, the pericardium, is folded around the heart, and the two serous bags, the pleuræ, are folded around the lungs.

Then in the mucous membrane of the stomach, just as in the mucous membrane of the mouth, there are certain depressions which we call glands.

In the first place, there are a large number of comparatively simple depressions, which are chiefly situated at the left end of the stomach, which goes by the name of the cardiac end, because it is below the heart. These depressions secrete a fluid called mucus, and so go by the name of mucous glands.

Besides that, there are in the stomach some long deep depressions, tubular glands, which secrete a special kind of fluid. This fluid, because it is secreted in the stomach, goes by the name of *gastric juice*, and the glands are called gastric glands. This juice is an acid liquid, capable of dissolving certain important parts of the food (parts which I shall mention more particularly when I come to speak of foods), viz. the fleshy parts, and of reducing them to a condition in which they are capable of being absorbed into the blood. The gastric juice, you will notice, is poured out by glands, which are situated at the end of the stomach, at which the food goes out. And so you see that even in our stomachs, one part of the stomach does not do precisely the same thing as another, and you have thus shadowed out the idea of the complex stomachs of certain animals which have foods very difficult to digest. For instance, cows and sheep have several stomachs, *i.e.* their stomach has several distinct compartments, and in each certain things are done. We have one, but still, at the same time, different parts of it have different

kinds of glands, which secrete different kinds of fluids for different purposes.

When the food gets into the stomach, its contact with the walls of the stomach causes the muscular fibres of the walls to contract, and the gastric juice to be formed, and it is not formed by the glands without the stimulus caused by the presence of food in the stomach. It is very fortunate that this is so, as otherwise it would digest the stomach itself.

By means of the movement of the walls of the stomach, caused by the contraction of its muscular fibres, the gastric juice that is secreted by the glands is mixed up with the food in the stomach, and every part of the food is brought into contact with the walls of the stomach, and so into contact with the gastric juice that is being secreted, and the parts that the gastric juice has acted on and dissolved flow gradually towards the right end of the stomach, and there, the circular fibres which go round the stomach, are packed very closely together, and form what is called a sphincter muscle; this is capable of contracting and protecting the opening, so that nothing shall go out of the stomach into the intestines, and is also capable of being relaxed, and letting digested food go out; it goes by the name of the *pylorus*, from the Greek word meaning a gate, and so the right end of the stomach is called the pyloric end.

The digested parts of the food which have become liquid pass on through the pylorus into the intestines, and the parts of the food that are more difficult of diges-

tion, and are not much acted on by the gastric juice, remain in the stomach and get a double chance.

I have told you that when the food is going down through the gullet into the stomach the starch is changed into sugar, but if any of the starch should not have been changed into sugar as it goes down before it gets into the stomach, no more is changed there. The acid gastric juice prevents that action going on, and the liquid that runs out of the stomach into the small intestine is an acid liquid that goes by the name of *chyme*. The walls of the small intestines are very like the walls of the stomach or of the gullet, but present a remarkable peculiarity. The inner wall of the small intestines, that is to say the mucous membrane, is not smooth as it is in the gullet or in the stomach, but is folded up into a large number of folds, which run around the intestines; the lining membrane of the walls of the intestines then is not straight, but folded up into a large number of folds. The effect of that folding is to immensely increase the surface of the mucous membrane. The small intestines are four times the length of the body, so that this folded mucous membrane is of very considerable length. Besides that, there is an immense number of little projections from this mucous membrane; they go by the name of the *villi*, and very much resemble the pile of a piece of velvet. These projections, as you can see, immensely increase the surface; they project so that the interior of the small intestines is like a piece of velvet folded up in a very complicated way, so as to get the greatest amount

of it into the shortest space. It is from the surface of these small intestines that the greatest part of the absorption of the nutritive material of the food, into the blood, takes place. In these little villi of the small intestines the lymphatics of the small intestines begin, and these, as I have already told you, are called lacteals; outside the beginnings of the lacteals in the villi there is a network of capillary blood-vessels.

Now, the chyme that is running out of the stomach goes into the *duodenum*, or first part of the small intestine, and almost as soon as it gets into the duodenum there is a discharge into it through one tube of two secretions: these secretions are the bile from the liver, and the pancreatic juice from the pancreas or sweetbread. The pancreatic juice very much resembles the saliva of the mouth, and it and the bile are both alkaline, and when mixed with the chyme they make it alkaline, and then it goes by the name of *chyle*. What do these two juices do? I have just said that they make the food alkaline instead of acid; but they do more; the pancreatic juice, in the first place, acts upon the remainder of the starch that has not been acted on in the mouth, and converts it into sugar, and both it and the bile together do another very important work.

It will have been noticed that no mention has been made of the fats in the food being acted on in the mouth or in the stomach, but when they reach the intestines, and are mixed with the two juices just mentioned, they are divided into an immense number of exceedingly small particles which spread out through the whole of the liquid,

so that the liquid becomes something like milk, and for the same reason, viz., because the fat in it is divided up into an immense number of very small particles. When you let milk stand, some of them rise to the surface and form the cream, but still a sufficient number remain to render it opaque, so that milk, among other things, is really an emulsion of fat. The fat that is contained in the food is then reduced by the two fluids before mentioned into the condition of an emulsion; so that you see we have, when these fluids have been mixed thus with the food, starch changed to sugar, the fleshy parts dissolved by the gastric juice, and the fat divided into a state of very minute particles; the mineral substances, as well, that are soluble being already dissolved in the liquid. Then that fluid runs along in the way described, and gradually passes through the thin coats of the villi into the blood-vessels of the villi, and that which does not get into the blood-vessels passes farther on into the lacteals, so that those villi catch up all the digested parts of the food as it passes through this great length of small intestines; the particles of fat pass into the lacteals and give the fluid which they contain (called also chyle) the milky appearance from which the lacteals derive their name. You will say, We can understand that sugar and other dissolved substances can pass through the epithelium of the mucous membrane, but how can particles of fat do so? Suppose you take a bag of wash leather and put mercury into it, and squeeze it, that mercury will ooze gradually through in small particles; and so precisely in the same manner the

small particles of fat gradually work their way through the walls of the villi and into the lacteals, so that they, like the other nutritious parts of the food, as they pass along through the small intestines, are absorbed.

Several kinds of glands are situated in the walls of the intestines. There are glands which are collected together in patches, which go by the name of their discoverer, and are called Peyer's patches. These are the glands in the small intestines which are inflamed and ulcerated in typhoid fever, and in describing the precautions to be taken in typhoid fever, I shall beg you to bear in mind that those glands are inflamed and ulcerated, and may form holes.

The small intestine then winds about for a considerable time, and at last ends in what we call the large intestine. It does not end in the very extremity of the large intestine, but a little way from the beginning of it, and the piece that remains goes by the name of the *cæcum*, or blind end.

The undigested parts of the food, which cannot be absorbed, pass through the small intestine into the large intestine, into the part called the cæcum, and just there there is a fold of mucous membrane which acts as a valve, so that the undigested parts of the food cannot get back again. From the cæcum there starts out a little appendix, something like a worm in shape; this has a little tube running almost up to its end, and connected with the cavity of the intestine. This tube, so far as we know, has no use at all; it corresponds to certain things which are of more or less importance

in lower classes of animals, but although we have no idea of its use, if it has any, it may do a very great deal of harm; sometimes things that have not been digested get up into the end of this little tube, and they stay there and set up irritation, causing inflammation, which extends to the peritoneum, the bag which is folded around the organs of the abdomen, and then death almost always ensues. Things that are liable to get into that little appendix ought not to be swallowed; such things are the stones of fruit. A great many people die, without the cause ever being suspected, from cherry-stones getting into it.

The large intestine is continued from the cæcum, rising upwards on the right side of the lower part of the abdomen, forming what is called the ascending colon. It then runs across below the stomach, and downwards on the left side, and it ends in a straight piece which goes by the name of the rectum. The walls of the large intestine are very much the same as those of the small, only that the muscular fibres running along it are collected in strong bands, so that they pucker it up, and throughout the course of the large intestine very little is done with the food, except that the more indigestible parts of it are passed along in order to be got rid of; though probably a little absorption occurs as well.

LECTURE V.

THE LIVER AND THE EXCRETORY ORGANS.

THE liver is the largest gland in the body. It is an organ situated on the right hand side of the abdomen, immediately underneath the diaphragm, to which it is attached by a strong fibrous ligament. It runs from the back right to the front of the abdomen close underneath the diaphragm, and its front edge overlaps the stomach.

I have already told you that a large portion of the blood of the body, namely, the blood which comes back from the walls of the stomach, the intestines, the spleen, and pancreas or sweetbread, and from a great part of the serous bag in which the intestines are enveloped, instead of going direct into one of the venæ cavæ, is conveyed into one large vein, which goes into the liver.

Now, besides that vein, an artery goes to the liver from the aorta or great artery which supplies the body. These two, the artery and the vein, go into the liver at the same place.

I have just said that the liver is a gland, and I have before said that when I speak of a gland I mean a true gland, and I mean by a true gland an organ that is formed around a projection from the skin or the mucous membrane of the body, or, if you like, that has a tube from it leading to the surface of the skin or of the

mucous membrane; that tube we call the duct of the gland.

The liver I call a gland, then, and it has a duct or tube leading to the surface of the mucous membrane, viz., the mucous membrane of the small intestines near their beginning. That duct is called the *bile-duct.* It comes from the liver, and it comes from the same place where the vein and artery enter the liver; so that we have three vessels, the vein and the artery going into, and this bile-duct coming out of, the liver at the same place.

If we follow them we find that they run through the substance of the liver together, and that their branches run alongside of one another, and are enclosed in the same fibrous capsule.

We find, further, that the portal vein and the artery send out still smaller branches into the very intimate structure of the liver, and that they each end in capillary vessels, and in *the same set* of capillary vessels, between the little pieces of which the liver is composed, called by anatomists the lobules of the liver.

These capillary vessels then run into the lobules and are collected into small veins, which start from the middle of those lobules of which the liver is composed, and run on joining one another and forming larger veins, at last to join together in one large vein, leaving the liver in another place and entering the vena cava inferior, which runs close behind the liver through the diaphragm to the right auricle of the heart.

The bile-duct is contained in the same capsule as the

portal vein and the liver artery, and begins by small branches in between the lobules of which the liver is composed; these small branches run together and form the proper duct of the liver—the bile-duct.

What goes into the liver? In the first place, the arterial blood goes to the liver by the liver artery, just as it does to every other organ of the body; then, in the next place, venous blood goes into it by the portal vein. That venous blood is blood that comes chiefly from the walls of the stomach and small intestines.

You remember I told you that in the small intestines a very large proportion of the soluble matter of the food is absorbed by the capillary vessels in the villi of the mucous membrane.

So you see that the liver is in the first place supplied with arterial blood, and in the second place with blood containing a large proportion of the nutritious parts of the food. What does it do with that blood? The most obvious answer is, that it secretes bile from it; but it does something else of far greater importance.

It is found that whether there is any sugar or not in the blood which goes to the liver, this organ has in some way or another the property of preparing from the blood a kind of starch, which goes by the name of liver starch, and by half-a-dozen other names, and the liver prepares at the same time another substance, which is called a ferment, and which is capable of changing that starch soon after it is made into fat, so that the liver is a kind of manufactory of fat; it is able to manufacture a kind of substance resembling starch out of the blood, and to

store it up for future use, and it is capable also of turning that same substance into fat. That is the first and most important property of the liver. That leads us to see why it is that the blood that has been absorbed, containing some of the most nutritious parts of the food, should go straight to the liver and not first to the tissues of the body to nourish them.

The liver, besides this, secretes bile. It separates from the blood a liquid having very important properties, which is partly a waste liquid, and partly useful. Bile has the property of helping the pancreatic juice to subdivide the fats, so that they are capable of being absorbed into the lacteal vessels, and it contains important resinous matters which stimulate the action of the intestinal canal, so that whenever anything occurs to prevent the proper secretion of bile by the liver the action of the intestinal canal becomes at once very sluggish; it does not get the stimulus that the resinous matters in the bile provide; the bile acts also as a very important antiseptic, and when its secretion is in any way impeded, the food is very liable to decomposition in the intestines. So you see that the liver is a very important organ.

A great part of the bile is absorbed into the blood, so that as it is absorbed into the blood of the intestines, and comes back through the portal vein to the liver, it would seem as if certain parts of the bile travelled in a circle to and from the liver. Only a small portion of the bile, more especially the colouring matter, is excreted as waste matter.

The liver is also said by some physiologists to be one of the sources of the white corpuscles of the blood. It is known that in the blood that leaves the liver a larger proportion than usual of white corpuscles exist. It is believed to be an organ in which waste red corpuscles are got rid of (because they waste, just as all the other parts of the body do), and some parts of the bile consist of substances of which these red corpuscles were composed.

You see already, from what I have told you, that in the liver certain substances are separated from the blood, and certain substances added to it.

I will go on at once to speak of the important organs which separate the waste substances from the blood; they are called Excretory Organs, and are the lungs, the skin, and the kidneys. The LUNGS I have already described to you, but I want to remind you of this, that the lungs are organs the interior of which is in connection with the external air, organs which are very highly supplied with blood, organs in which the blood is brought into almost immediate contact with the external air, being only separated from it by a fine moist membrane. The lungs separate from the blood, in the first place, waste carbon in the form of carbonic acid. Now carbon, or charcoal, is a substance that is contained in almost all our tissues, and in almost all our foods, so that it is a substance that is being continually added to the body, and has to be continually got rid of. The amount of carbon, in the form of carbonic acid, that is got rid of by the lungs of an adult

in twenty-four hours is very nearly eight ounces, or half a pound. Besides carbonic acid, water, on an average about nine ounces, or very nearly half an imperial pint, is got rid of from the lungs of each individual in twenty-four hours, and also a certain amount of foul organic matter.

The other excretory organs—the skin and the kidneys—get rid of these same substances, water, carbonic acid, and organic matter; and the kidneys, in addition, remove large quantities of mineral salts.

The SKIN of the body consists of two chief layers. The first, or outer layer, goes by the name of the scarf-skin or *epidermis.* It is insensible, horny, not supplied with blood, dead, and consists of scales, which are continually falling off. The deeper layer is very largely supplied with blood, running, of course, in capillary vessels, and a certain amount of exudation from that is able to take place through the epidermis or scarf-skin. This is of very small importance, but of much greater importance is the fact that certain substances are separated from the blood in the true skin by means of glands. There is an enormous number of glands situated in the true skin of the body. These glands are true glands. They consist of structures around projections from the surface of the skin, and go by the name of *sudoriparous* or sweat glands, or perspiration glands.

Each of these glands consists of a long tube that is pushed in from the epidermis, as it were. It starts at the surface or scarf-skin, and runs through in a cork-

screw-like fashion into the true skin, and is there twisted up into a ball, which contains a very large number of capillary blood-vessels.

By these sudoriparous or perspiration glands, a fluid is secreted, consisting of water having a very small quantity of salt and organic matter dissolved in it. It is found also that by these glands a certain quantity of carbonic acid gas is got rid of from the blood, and that through them a small quantity of oxygen gas gets into the blood, so that you see the action of these glands is similar to the action of the lungs, only that the quantities of the substances got rid of are different. From the lungs a large quantity of carbonic acid is got rid of—from the glands a very small quantity; on the other hand, in twenty-four hours, about twice as much water is ordinarily got rid of from the perspiration glands as from the lungs—*i.e.*, about eighteen ounces. This amount varies with the temperature, exercise taken, etc.

The number of these glands that are found in the true skin varies very much in different parts of the body, but altogether there are two and a half millions on the surface of the body. The openings of their tubes are commonly known as the pores of the skin.

There are other glands in the true skin which do not perform the functions just described.

Connected with the scarf-skin there are certain structures in different parts of the body which are peculiar varieties of the epidermis or scarf-skin: such are the nails and hairs.

In connection with the hairs there are certain little

glands called *sebaceous*, or, if you like, little glands which secrete an oily fluid, a kind of natural grease for the hair and skin. It keeps the hair and skin constantly lubricated. I may also mention here, that attached to the roots of the hairs in the skin there are small involuntary muscles, the object of which is clearly to move the hairs. They are capable of contracting under certain very strong stimuli, and when we say that a person's hair "stands on end" when he is very much astonished or under strong excitement, it is not a fiction, but literally the fact. Any strong emotion may indirectly cause the muscular fibres to contract, and the hair to stand on end.

From the surface of the skin, just as from the lungs, besides the substances that are got rid of from the blood, heat is lost. I told you that a considerable quantity of heat is lost from the lungs, so, too, a considerable quantity is lost from the surface of the skin. Now, this action I have just described of the perspiration glands in the skin is an action of extreme importance, and so it is of the greatest importance that we should keep the surface of our skin continually freed from the secretion of these glands which is being continually poured out. The action of these glands is continually going on although we do not notice it. Water is continually evaporating from the surface of the skin.

The continual action of these glands goes by the name of insensible perspiration. When we visibly perspire, it is because, from some reason or other, these glands act more than usual, and secrete so much fluid on the

surface of the skin that it cannot be got rid of by evaporation as quickly as it is formed. It is of extreme importance, however, that it should not accumulate, and so choke up the pores of the skin, as is commonly and quite rightly said. If this is allowed, then much of the action of the skin in separating waste substances from the blood is thrown upon the other excretory organs—viz., the lungs and the kidneys—and these organs get too much to do, and so become diseased. This is one cause why towards the latter end of life those organs frequently become diseased. You can actually as certainly kill an animal by varnishing his skin over as by cutting his throat.

The KIDNEYS are two organs situated in the abdomen, one on each side of the vertebral column; their shape is well known, and needs no description. These organs are true glands; each has a duct which indirectly communicates with the external air.

If we cut a kidney across, we find that the duct (which goes by the name of the *ureter*) is funnel-shaped where it leaves the kidney, and pointing into that funnel-shaped head of the duct, there are some conical masses of kidney substance; they go by the name of the *pyramids of the kidney.* When these are examined very carefully, it is found that there are an immense number of fine tubes running through them, called the *tubules* of the kidney, and they open out at the end of these pyramids, and run straight through the interior substance of the kidney, and then into the outer part of the kidney, where they twist about a great deal. These

tubules, when examined under a microscope, are found to end in little bags or *capsules.* The interior of these bags or capsules is in indirect communication with the external air, because from these little capsules the tubules of the kidneys start, and ultimately open, on the surface of the pyramids, into the funnel-shaped beginning of the ureter—the tube which leaves the kidneys and which is indirectly connected with the external air. Now, an artery comes to each kidney—we will call it the kidney artery ;—it subdivides into small branches; these small branches go through the substance of the kidney until they come to the outer part of it, and then they end in very small branches, which go straight into the capsules just mentioned; each small branch of the artery goes into one of the capsules, and immediately breaks up into a bunch of capillaries, forming a little ball in the interior of that capsule, and that little ball, as it were, pushes the lining membrane of the capsule before it, so that between that little ball of capillaries and the interior of the tubule connected with the capsule there is nothing but that very fine lining membrane. Then the capillaries in that little ball run together, forming a small vein that goes out from the capsule. These small veins do not join together to form the vein that leaves the kidney; they do like the portal vein—they break up into capillary vessels surrounding the tubule; these capillary vessels then join together and form a little vein, and then numbers of these little veins join together and form the kidney vein which leaves the kidney.

Now, I want you to see that the kidney is built upon the same theory as the other two excretory organs —the skin and the lungs.

In the kidney, blood is brought by the kidney artery into the little capillary vessels inside the capsules, and so the blood in these capillary vessels is separated from the interior of tubes connected indirectly with the external air merely by a fine, moist membrane. That is the plan of construction in all these excretory organs; they are all contrivances by means of which blood in the capillary vessels is brought into the nearest possible connection with the external air, brought into connection with tubes connected with the external air, only being separated from the interior of these tubes by a fine moist membrane; and so there are points in all these excretory organs which are similar — the waste substances go through the walls of capillary vessels, and through fine membranes ultimately into the external air. By means of the kidneys, the following things are got rid of from the blood: in the first place, water, to the extent of about fifty ounces, or two and a half imperial pints, in the twenty-four hours; that water contains certain things in solution: it contains a substance which goes by the name of *urea*, a waste organic substance, of which I shall have more to say when speaking about foods; the kidneys get rid of this substance to the extent of 500 grains in the twenty-four hours, and of another organic body called uric acid, in much smaller quantity: besides this, there are mineral salts, such as common salt, and carbonate and phosphate of lime, and

a good many other salts of, perhaps, less importance; so that you see we get rid of the same substances from the kidneys as from the lungs and skin—water, carbonic acid in the form of carbonate, and organic matter in very large quantities, and also large quantities of mineral salts.

The quantities I have mentioned are the average amounts excreted by the kidneys of an adult in twenty-four hours.

One more thing we have to consider, and that is how this contrivance acts. The blood is brought by the kidney artery into the ball of capillaries, and the surplus water of the blood, with certain substances in solution, exudes from these capillaries and passes through the fine membrane (just as it would through a piece of filtering paper) into the tubule. Other matters are excreted through the capillaries which surround the tubule, and are then washed away by the watery excretion coming from the capsule.

A few words about the general changes that go on in the blood. The blood, you see, is being continually renewed from the nutritious parts of the food, partly by absorption from the walls of the small intestines directly into the capillary blood-vessels of the villi, and partly indirectly by absorption from the walls of the small intestines into the lacteal vessels, which, by means of the thoracic duct, convey their fluid into the blood.

It is renewed with nutritious substances from the food; the white corpuscles, from which we know the red ones are ultimately formed, are continually being formed in the lymphatic glands, and in the spleen, and

a few other so-called ductless glands, and perhaps in the liver; these white corpuscles are being continually made, and being added to the venous blood.

To this blood is also added the blood that has been purified in the way I have described in the kidneys, and all this mixture goes to the right side of the heart, is then pumped through the lungs, undergoes the alteration I have described there, especially loses carbonic acid and gains oxygen, then goes to the left side of the heart, and is pumped all over the body into the capillary vessels in the tissues; certain portions of the blood exude from the capillary vessels into the tissues; each tissue takes out what it requires for itself, and leaves the remainder, and, besides that, adds to the remainder the decayed portions of itself.

Whatever blood is not taken up by each tissue goes on into the veins, and to that is also added a certain quantity of the waste substance that comes through the capillary walls from the tissues into the blood; the remainder, viz., the fluid that was not required by the tissues, and some of the waste parts of the tissues, are taken up by the lymphatic vessels, and are conveyed by them into the thoracic duct, and so into the blood again.

While all this is going on, the oxygen gas that has been absorbed into the blood through the lungs is combining, especially in the capillary vessels in the different tissues, with the substances in the blood which are capable of combining with it; and it is combining notably with certain waste substances that the tissues have added to the blood; and I have told you that

this combination is attended with the production of heat (all chemical combinations are attended with the production of heat), and this is the way in which the warmth of our bodies is kept up. It is by the conversion of this animal heat, as we call it, into various forces, that we are able to move about, to think, and to do all the various acts that we perform. This combination of the oxygen of the air with substances in the blood produces the waste substances that we get rid of by the organs I have been speaking about,—by means, then, of the combination of oxygen with certain substances in the blood, heat is produced, and the waste parts of the tissues of the body are converted into substances which can be separated from the blood and from the body by means of the organs just described.

Now, a word on the importance of the regular and proper action of these excretory organs, and of the intestinal canal. The former separate substances from the blood that are hurtful if they are kept in the blood. The waste substances that are got rid of by the intestinal canal include the parts of the food that are not digested, and certain secretions from the intestinal canal, especially from the large part of the intestine. These substances are injurious if left in the body, as certain portions of them are reabsorbed into the blood, especially the foul organic matter in them, so that if these various excretory organs do not perform their functions in a proper manner, waste substances are either not separated from the blood or are reabsorbed into it, and poison it, and as the blood is distributed to the various tissues of the

body they are not properly nourished, and they become degenerated, weak, and incapable of performing their proper functions; so that the regular action of these excretory organs of the body is of the greatest importance with regard to health, for not a single tissue of the body can be kept in a proper condition if the waste substances are not got rid of in the manner they should be.

LECTURE VI.

THE NERVOUS SYSTEM.

THIS is the system which regulates and controls the action of all the other organs of the body. In us, and in the higher animals generally—*i.e.*, vertebrate animals—there are two nervous systems, one of which corresponds to the nervous system in the lower or invertebrate animals. That we call the great sympathetic nervous system.

I have told you already a little about it. It consists of two chains of nerve-cords running down, one on e ach sideof the vertebral column. These nerve-cords have knots upon them at intervals; knots, which we call *ganglia*, and nervous cords pass from these ganglia and form networks about the great organs or *viscera* in the thorax and in the abdomen.

In connection with these networks of cords there are other knots or ganglia, and from these smaller nerves are given off to the viscera and to the walls of the blood-vessels.

This great sympathetic nervous system, which I tell you corresponds to the only nervous system in invertebrate animals, like insects, snails, etc., controls the actions of the body, which we cannot influence by means of our wills, such as those of the involuntary muscles

of the walls of the stomach, intestines, and blood-vessels, and so it has especial control over the organs of vegetative existence.

The other nervous system consists of the brain and the spinal cord, and the nerves connected with them.

The brain and spinal cord are situated in a special cavity, consisting, you will remember, of the cranial cavity, and the canal, which runs down behind the bodies of the vertebræ, being formed by the rings, which are themselves formed by the arches at the back of the vertebræ. This canal we call the spinal canal, and it is inside that canal that the spinal cord is lodged.

The spinal cord and brain, besides having the bony walls of this cavity in which they are lodged for their protection, have certain membranes surrounding them. The first of these membranes is hard, tough, and fibrous. It lines the bony cavities, lying next to the bone. Then there is a very fine thin membrane, which closely invests the brain and the spinal cord throughout, and dips into all the irregularities of the surface both of the brain and spinal cord. This fine membrane carries a network of very fine blood-vessels, which are the vessels to supply parts of the brain and spinal cord with blood. Between these two membranes is a third, which is a closed sac of very fine membrane called the *arachnoid* membrane, from its resemblance to a spider's web, and which secretes fluid in its interior. So you see these great nervous structures are protected in a most remarkable manner. In the first place, in a bony cavity of their own, which is lined with a tough fibrous membrane, so that even if

part of the bone should be broken, this protects the nervous substance, which is itself invested closely with a fine membrane, and between these two there is a closed sac which secretes fluid in its interior, and keeps the whole soft and moist. These are the investing structures of the brain and spinal cord.

In describing this nervous system, we will consider the spinal cord first.

The spinal cord begins at the top of the spinal canal, where it joins a part of the brain, and it extends downwards to the vertebræ of the loins in the spinal canal, and then it subdivides into a quantity of strands, a kind of leash as it were. The spinal cord and the brain are similar on the two sides; they can be divided into two equal and similar halves; one side is just like the other side. If you take the spinal cord and cut it across and look at the section of it, you find that it is more or less oval in section, and that it has two fissures, one at the front, and one at the back,—the posterior and anterior fissures, as they are called; the posterior fissure is rather deeper than the anterior one, and reaches nearly to the middle, so that they almost cut it into two halves. And the next thing you see is that it does not look quite the same all through; it is not composed of one and the same substance all through; the greater part of it is made up of a white substance, the white matter of the spinal cord; but there is a greyish-red substance in it, disposed similarly in the two halves in such a way that in the section of it it looks somewhat crescent-shaped in each half; this goes by the name of the grey matter of the spinal cord.

These two crescent-shaped patches, as it were, of grey matter are joined across the middle, where the two fissures do not meet, by more of this grey substance, and in the middle of that there is a little canal which runs the whole length of the spinal cord and is called the central canal of the cord. That is the rough anatomy of a section of the cord in a very few words.

You will see also that a considerable number of branches, as it were, leave the spinal cord; these branches are called nerves, and because they leave the spinal cord they are called the spinal nerves. They leave the cord similarly on each side, thus forming pairs, so we speak of pairs of spinal nerves, and there are thirty-one of these pairs. The next thing that you notice about these nerves is that each of them springs from the spinal cord in two pieces; these pieces are called the roots of the nerve, so that each spinal nerve has two roots; one of these roots comes from the front and the other from the back of the spinal cord; these two roots join and form a single trunk, which goes by the name of the spinal nerve. Just before these roots join there is a swelling or knot, which we call the ganglion, upon the posterior root.

If you take the section of the spinal cord you find that the posterior root of the spinal nerve starts from the posterior horn of the crescent of grey matter, and that the anterior root starts opposite to the anterior end of this crescent of grey matter. Upon the posterior root there is the swelling or ganglion before mentioned, and then the anterior root joins it, and they form the trunk

of the spinal nerve; and that is how each of these spinal nerves belonging to the thirty-one pairs of spinal nerves is formed.

These spinal nerves, then, are distributed to different parts of the body. Those from the upper part of the spinal cord are distributed chiefly to the muscles and skin of the neck, and the parts near to the neck. Those a little farther down are distributed to the arms—to the skin, and to the muscles of the arms. Those in the dorsal and lumbar regions are distributed to the walls of the chest and abdomen, both to the muscles and the skin; while the lowest of them form the largest nerves in the body, called the sciatic nerves (from which the disease sciatica gets its name), which go to the lower limbs.

I have told you that these spinal nerves are distributed to the muscles of the parts, and to the skin of the parts. Now, of what use are they? What is done by means of them? If you take a nerve belonging to this system, a branch of one of the spinal nerves, in any part of the body of an animal, and irritate it by means of a needle, or in any other way, two things happen. In the first place, the animal feels pain and shows signs of it; and, in the second place, the muscles to which that nerve goes contract. And where is the pain felt? The pain is not felt where the nerve is irritated at all; the pain is felt in that part of the skin to which the nerve goes, so that if we have irritated the trunk of the nerve—say in the fore-leg of the animal—the pain is felt just as if you irritated the extremities of the nerve in the skin. Now suppose you take the trunk of a spinal nerve and cut

it in two, and then irritate the end of it which is still in communication with the part to which that nerve goes, but which is no longer in communication with the spinal cord, then only one thing happens: the muscles to which that nerve goes contract, but the animal feels no pain whatever, and shows no sign of it; suppose, on the other hand, you irritate the end which is no longer in communication with the part to which the nerve goes, but which is still in connection with the spinal cord, then the animal feels acute pain and shows signs of it, but no muscles contract; that shows you that the stimulus which causes the muscles to contract travels along these nerves from the spinal cord towards the muscles that are contracting, and by contraction moving the different parts of the body, and that the stimulus which causes pain travels, on the other hand, along these nerves towards the spinal cord; and, more than that, if you cut through a piece of nerve and irritate the end of it which is still in connection with the spinal cord, the animal refers the pain to the extremities of the nerve, just as if they were being irritated.

That shows us that these nerves have two properties, —that they are capable of conveying stimuli from the spinal cord where they rise to the muscles to which they go to cause them to contract, and they are capable of conveying stimuli from the skin, to which some of the branches go, to the spinal cord; they, therefore, convey stimuli both ways, and for that reason are called mixed nerves.

Now let us go on to consider the two roots. Suppose

that in an animal you cut through the front or anterior roots of some of the spinal nerves and leave the others alone, what happens? It is found that the animal is no longer capable of contracting the muscles to which these nerves go by means of the will, but that he feels pain in the parts to which these nerves go, just as he did before; that shows at once that the stimulus which is started by means of the animal's will travels through these anterior or front roots of the nerves; it travels through them and along the nerves to the muscles to which the nerves go; these anterior roots are for that reason called the *motor* roots of the nerves; it is through these anterior or front roots that the stimuli travel which produce contraction of the muscles and so movement, and that can be proved to still greater demonstration by taking these cut pieces and irritating with a needle that part of the root which is still in connection with the nerve; that irritation produces no pain whatever, but the muscles contract.

Suppose, instead of cutting the anterior roots of the nerves, you cut the posterior roots of a few of these nerves, then it is found that the animal no longer feels at all in those parts of the body to which the nerves go, the posterior roots of which have been cut through, but he is perfectly capable of moving the muscles of those parts. Suppose, for instance, you cut through two or three of the posterior roots of the nerves that go to the fore-leg of the animal or to the arm of a man, then the animal is perfectly capable of moving the muscles of that limb, but he is no longer capable of feeling in that limb,

or in the parts of the limb to which they go. It may be put into the fire, into strong acid, anything may be done with it, and the animal knows nothing whatever about it, so that the stimuli of sensation travel along the mixed nerves and to the spinal cord by means of the posterior roots of those nerves, and for that reason the posterior roots of the spinal nerves are called *sensory* roots; and you see now still better why these spinal nerves go by the name of the mixed nerves—they are made up of these two roots, and these two roots have distinct properties,—one of them conveying stimuli from the spinal cord towards the parts of the body to which the nerves go, and the other from those parts of the body towards the spinal cord,—the one the anterior or motor root, the other the posterior or sensory root.

Let us speak a little about the properties of the spinal cord itself.

If you cut through the spinal cord of an animal somewhere in the back, right across, then the animal has no longer any control whatever over the muscles of the parts of the body which are supplied by nerves coming from the part of the cord below the cut, and he is also deprived of sensation in those parts of the skin supplied by the same nerves.

Supposing that, instead of cutting through the whole of the spinal cord, you cut through the front part of it, so as to cut right across the white matter of the front of the spinal cord, it is then found that the animal is no longer capable of moving any muscles on either side of the body supplied by nerves below that cut, so that this

shows that the stimuli which cause the movement of the muscles of the body travel down through the white matter in the front part of the spinal cord.

If, on the other hand, one half of the cord be cut through—say on the right side—then it is found that the animal has lost all power of moving the muscles of the right side of the body supplied by nerves from below the cut, so that the stimuli which cause the movement of the muscles travel down the spinal cord upon the same side as the muscles which are to be moved. But he has lost sensation on the other side of the body in the parts of the body supplied with nerves below that cut, so that it is clear that the paths which convey sensation up the spinal cord travel up the opposite side of the cord,—the paths which convey sensation from the left leg, for instance, up the spinal cord, travel up the right hand side of the spinal cord, and the paths which convey sensation from the right leg up the spinal cord travel up the left hand side of the spinal cord.

I have told you already, from the simple experiment of cutting through the white matter of the front part of the spinal cord, that the stimuli causing movement travel down the white matter of the cord. If you cut through the white matter of the front part of the cord in one place, and the white matter of the back part in another place, so that with the two cuts you have cut through the whole of the white matter, only in two different places, it is found that sensation is not interfered with; so that it is clear that the paths which convey sensation in the spinal cord travel in the

grey matter in the spinal cord, which you have left untouched.

So we come to this, that the stimuli which cause movement and the stimuli of sensation are conveyed along the spinal cord. If you cut the spinal cord clean across, the conveyance of these stimuli is stopped altogether. That the stimuli which cause the movement of the muscles are conveyed in the white matter of the front part of the spinal cord towards the muscles that are going to be moved, and on the same side of the cord as the muscles are that are going to be moved; that the stimuli which pass from the different parts of the body up the spinal cord travel up in the grey matter of the spinal cord, and on the opposite side of it.

So we see that the spinal cord is a great conductor of impressions to and from the different parts of the body; but it is more than this. When you have cut through the spinal cord of an animal, I have said that he cannot feel anything in the parts to which the nerves below the cut go, and that he cannot move any of the muscles of his own accord; but if you take that animal and tickle the soles of his feet, or irritate the skin in any way, he will kick out; if he does not feel how can he do that? It is not he who does it at all; it is not his will; the animal shows no sign of pain, and does not know anything that is happening to that part of his body, but still the muscles in that part of his body contract violently, and the parts are moved; and that shows a very remarkable thing, that the spinal cord itself is capable of originating movement, that it is capable in

some way of itself interpreting sensation and of commanding movements independently of the will of the animal. Now, movements of that kind, which are produced entirely without the will of the animal, go by the name of *reflex* movements; they are so called from the idea of reflection. It seems as if stimulus applied to the skin at a certain part of the body is conveyed through the posterior roots of the spinal nerves to the part of the spinal cord which is no longer in connection with the brain, and as if that part reflected it along the motor roots of the nerves to the muscles to be moved, and that is why such acts are called reflex acts.

Reflection is not a very accurate simile, because if you irritate a part of the skin, however small, if you irritate a nerve, or a very small branch of a nerve, that irritation is transferred to the spinal cord along perhaps only one of these nerves; or if you irritate the posterior root of one of these nerves after it has been cut through, not only the muscles to which that nerve goes contract, as you would expect if it were merely a kind of reflection, but that stimulus is distributed in the grey matter of the spinal cord, and stimuli are sent along many motor roots on both sides of the cord, so that a large number of muscles are moved. The grey matter of the spinal cord, from being capable of originating such movements itself, is called a *nervous centre.* So you see the spinal cord has two different functions: it is a conductor of impressions, both of stimuli which produce movement and of those which cause sensation, and it is also an independent nervous centre; and, more

than that, if you cut through the cord in two places, the part that is left between the two places is an independent nervous centre, capable of interpreting sensations that come to it, and sending messages along the anterior roots of the nerves connected with it to the muscles to which they go, and causing them to contract. Now you see what we mean when we speak of a nervous centre.

These nerves that I have been speaking about are made up of bundles of fibres, nerve fibres, and each of these nerve fibres can be shown to consist of a little tube with a little thin cord running down its centre inside of it. The nerves are made up of these bundles of nerve fibres, and you will see at once that these nerve fibres bear a strict analogy in their construction to the telegraph wires which are laid down under the streets, and consist of copper wire with a coating of gutta-percha. The white matter of the spinal cord is made up also of these nerve fibres running the whole length of the spinal cord. The grey matter is made up of large irregular star-shaped bodies, which go by the name of nerve cells. Now I have made a comparison with the electric telegraph, and you will see from what I have already told you, how far that comparison holds; it holds to a very large extent.

When the skin of a part of the body is irritated, a message is started along the nerves up to the spinal cord; it goes into the grey matter which we call the nervous centre of the spinal cord; that grey matter is like a telegraph office: it takes note of this message, and then it sends messages along the fibres, which go through

the anterior roots of certain spinal nerves to the muscles to which these nerves go, and causes them to contract.

Now, the spinal cord at its upper part joins the brain, and the part of the brain that it joins appears like a direct continuation of the spinal cord; that part goes by the name of the *medulla oblongata* or prolonged marrow.

Several very important nerves, which I shall have to speak of bye and bye, rise from it.

The fibres of the anterior columns of white matter, along which the stimuli which cause the muscles to contract travel, cross one another in the medulla.

The little central canal of the cord opens out into a wide cavity on the posterior, or rather upper surface of the medulla oblongata. This wide cavity is covered by the middle part of the small brain or *cerebellum*, which is at the lower part of the back of the head, and has two halves which are precisely similar.

In the brain there are certain cavities which go by the name of *ventricles*, and the cavity just underneath the small brain and above the prolonged marrow is called the fourth ventricle; then at the upper part of the prolonged marrow, nerve fibres cross over from one side of the small brain to the other, forming the bridge or *pons*, and the fibres which have run up the spinal cord, right through the prolonged marrow, run underneath these fibres that cross over and between them, and then emerge beyond in two bundles. These bundles go by the name of the legs of the brain; one bundle goes to each side of the great brain or *cerebrum*, and their fibres

run on through certain large bodies in the lower part of the brain, which we call the *ganglia at the base of the brain*, consisting partly of grey matter and partly of white matter, so that you see now that these ganglia at the base of the brain are connected by fibres, which run right down through the spinal cord into the spinal nerves of the different parts of the body; and from what I said just now you will see that the fibres which form the right anterior column of the cord come from the left side of the brain, and *vice versa;* so that injury to one side of the brain causes paralysis of the other side of the body. Surrounding the ganglia at the base of the brain, there is the large mass of brain proper. Now this large mass of substance, unlike the spinal cord, which is white outside and grey inside, has the grey matter outside and the white matter inside, and this is true, both of the large brain and the small brain. The surface of this grey matter and also the quantity of it is increased very considerably by a device, viz. by the doubling of the surface of the brain into a large number of folds, which go by the name of the *convolutions* of the brain, and are separated from one another by furrows. The two halves of the great brain, like the two halves of the small brain, are connected together by the fibres which run across. These fibres form a thick, hard, white body, that joins the right side of the brain to the left, and so these two sides of the brain are in continual communication with one another. If it were not for the band of white fibres and one or two other structures, one-half would be separated from the other.

The grey matter on the outside of the brain is connected, by means of the white matter beneath it, with the ganglia at the base of the brain, and these ganglia are connected by means of fibres which pass through the two legs of the brain, with the prolonged marrow and the spinal cord, and so by means of the nerves with the different parts of the body.

From the brain, just as from the spinal cord, nerves start; these were divided by the old anatomists into nine pairs, because they pass out of the skull by nine openings on each side; the old anatomists considered that the nerves that pass through one hole belong to one another, and so they counted nine pairs of nerves. Now they are divided into twelve pairs. I am not going to tell you all the pairs of these nerves, but I will tell you of one or two of the more important ones.

The first pair of these cranial nerves are called the *olfactory* nerves; they go to that part of the nose in which the organ of smell is situated; they are the nerves by which the stimuli which cause the sensation of smell are conveyed to the brain.

These nerves do nothing else; no muscles are caused to contract by means of them, and no other kind of sensation than that of smell is conveyed by them, so you see here we have a different class of nerves, all the spinal nerves having two properties; muscles were moved by means of them, and sensations were conveyed by means of them. The second pair of nerves start one from each side of the brain; they join one another, or rather are connected together by a band of nerve fibres, and then

pass forwards, one to each eyeball. These are the nerves which belong to the sense of sight; they are called the *optic* nerves, because they convey the sense of sight to the brain, they do nothing else whatever. These first two pairs of nerves are examples of purely sensory nerves. The third pair are the nerves, by means of which most of the muscles which move the eyes are made to contract. The fourth and sixth pairs supply those muscles which move the eyeball, and which are not supplied by the third pair. In the third, fourth, and sixth pairs of nerves we have examples of nerves which only influence muscles.

The fifth pair of nerves are the largest pair of nerves which start from the brain, and they resemble spinal nerves in that each of them has two roots,—a motor root and a sensory root, with a ganglion upon the latter; they are mixed nerves, motor and sensory. They supply the skin of all the face, the mucous membrane of the mouth and nose, the teeth, and certain muscles of the upper and lower jaws.

I have mentioned the sixth pair already; the seventh pair of nerves are called the *facial* nerves, because they supply the muscles of the face; they are purely motor nerves.

The eighth pair were counted as part of the seventh pair by the old anatomists, and are the nerves which go to the organs of hearing, conveying the sensation of hearing from the organs of hearing to the brain; they are called the *auditory* nerves, and are purely sensory.

Now, I need not go on mentioning all these nerves,

but the nerves of one more pair are so important that I must speak to you about them. One pair of the nerves which rise from the medulla oblongata, leave the brain and go to other parts of the body than the head; these nerves go by the name of the *pneumogastric* or the *vagus* nerves, from their wandering course; they supply the larynx in which the voice is formed, part of the pharynx, the windpipe, the œsophagus or gullet, the lungs, and going along by the œsophagus, pass through the diaphragm and supply the stomach; they also give branches to the heart. So you see that they are extremely important nerves. They go a long way, and supply important organs—the heart, the lungs, the œsophagus, the larynx, the stomach, and others, and that is one of the reasons why the medulla oblongata, from which they start, is such an extremely important part of the nervous system.

You may cut off the brain of an animal entirely, so long as you leave the medulla oblongata untouched, and he will go on living; he has no senses, but lives for some time, because this pair of nerves which supply the heart, the lungs, the stomach, etc., is left untouched.

Not only so, but fibres from all the cranial nerves, except the first two pairs, have been traced into the medulla oblongata.

The small brain has the property of co-ordinating the muscles on the two sides of the body; of causing the muscles of the body to act in concert with one another. When the small brain is injured the animal does not walk straight, but twists round and round.

The ganglia at the base of the brain are nerve centres, which are capable of acting independently of the will; they are connected with most of the nerves that belong to the brain.

Now, we know that reflex actions are capable of being performed by the spinal cord independently of the will; such actions are also capable of being performed by means of the nerves which belong to the brain. For instance, when we see a flash of lightning, or when a lighted candle is passed near to our eyes, we wink unconsciously. And not only so, but if you pass something quickly in front of a person's eyes it will make him wink; he cannot help it, even if he tries to; so that is an action which occurs not only independently of, but even in spite of, the will, and is a purely reflex action. It is produced by the stimulus travelling along the optic nerves from the eyes to the ganglia at the base of the brain, causing the sense of something coming too near the eyes, upon which these ganglia at the base of the brain immediately start a stimulus along the nerves which go to the muscles of the upper eyelids, causing these muscles to contract and pull down the eyelids; that is a reflex action performed by the brain, and entirely independently of the will of the animal, so that these ganglia at the base of the brain are capable of originating actions, movements, without our knowing anything about it.

Which, then, is the part of the brain that has to do with consciousness? It is the grey matter on the surface of the brain. In it resides our will, and all our

higher powers as animals. As we ascend in the scale of animals that grey matter becomes more and more in extent, the convolutions of the grey matter become more complicated, and it has even been distinctly shown that men of transcendent ability have been found to possess brains, not only of great weight, but with an extremely complicated surface, and so a greater quantity of grey matter on the surface of the brain; so that we have no doubt at all that the grey matter is the centre from which all the impulses which we know anything about are started, and investigations have been in progress for finding out the parts of the body controlled by the different parts of this grey matter.

A word about phrenology. By phrenology people pretend to tell you the character of a man by the examination of his skull. Now, if they could examine his brain, and find out what these different parts of the brain do, there would be some sense in it, but they do it by the shape of the skull. I will tell you a fact that is a very hard one for phrenologists, and that is, that there is no one part of the brain which is always underneath a fixed part of the skull; you cannot put your finger on any part of the head and say what part of the brain is under it, so that if the brain has anything to do with character, it is clear that you cannot tell a character by means of the skull. There is, however, something in physiognomy; there is no doubt that a trace of character can be seen generally in the delineations of the face, and different parts of the body; and I might almost say that scien-

tific deductions have been drawn from the study of features; but what I want to point out to you is that you can draw no conclusion as to a person's character, except in the roughest way, from bumps on his skull.

Now, I hope you have all gathered from this lecture that the nervous system is made up of a series of contrivances which consist of nerve fibres going to and from nerve centres: fibres along which stimuli go *towards* the nerve centres are called *afferent* fibres, and those along which stimuli travel from the nerve centres towards parts of the body, are called *efferent* fibres. The whole of the nervous apparatus of the body is made up of elements, each consisting of an afferent fibre, a nerve centre, and an efferent fibre.

When you have a reflex action it is because a stimulus has come from some part of the body to a nerve centre, which stimulus is then started (generally being communicated to other nerve centres with which that is in connection) along efferent fibres to certain muscles, which are caused to contract. That is the whole theory; it is built up entirely upon that plan.

The ganglia at the base of the brain are connected by nerve fibres with the spinal cord, and thus by the spinal nerves with different parts of the body, as well as with parts of the head by cranial nerves. Stimuli come along these nerves, and ultimately reach the ganglia at the base of the brain. Now, if a purely reflex action is produced, it is because one of these ganglia at the base of the brain sends stimuli along efferent fibres to parts that are to be moved, and the animal knows nothing

about it. Such are most of the movements that I have been making during this lecture (unless when looking for a piece of chalk or a duster); they have been purely reflex actions, not natural reflex actions, because I could not have made them when I was born; they were acquired reflex actions, and performed in obedience to orders from the ganglia at the base of the brain, without my knowing anything about it. When the will comes into play, it is because the ganglion at the base of the brain which receives the stimulus, sends stimuli through the white matter of the brain to the nerve centres in the grey matter on the surface of the brain, from which a stimulus is sent back to another of these ganglia, and then that ganglion sends the stimulus on to the part to be moved. Suppose I find my finger touching, by accident, the chimney of this gas-light, a stimulus is sent,—a sensation of heat is conveyed along the nerves of my arm through their posterior roots,—into the spinal cord, up the grey matter of the spinal cord to the ganglia at the base of the brain, and a stimulus is sent from the ganglia to certain muscles that move my arm; they contract, and my hand is withdrawn before I know it; but if I determine to hold it there, then the sensation comes to the ganglia at the base of the brain, and is sent from them through the white fibres to the grey matter on the surface of the brain, in which my will, somehow or other, resides, or by means of which it manifests itself; that grey matter sends a command to the ganglia at the base of the brain, to cause these muscles to still contract, and keep my hand against

the hot place; that is the difference between reflex actions and the actions performed by the will; but you see that the plan of the apparatus is the same, the nervous "element" being simply doubled.

We know, for many reasons, that the higher powers,—intelligence, consciousness, will, and so on,—reside in the grey matter on the surface of the brain; if this grey matter on the surface of the brain be removed the animal loses all consciousness, and also pressure upon the grey matter on the surface of the brain causes unconsciousness. In young infants the bones of the skull do not meet together; there are spaces left where the bones are joined by membranes, and a good many nurses are in the habit, when children are peevish from indigestion or teething, of pressing their fingers on these membranes, which prevents them crying,—not because it cures the indigestion or the teething, but because it makes the children more or less unconscious, and insensible to pain.

One other thing, and that is the last. This grey matter, in which movements are originated, and sensations received and interpreted, which seems to command and arrange everything, is itself insensible.

LECTURE VII.

ORGANS OF THE SENSES.

LET us now consider the organs by which the brain and spinal cord are put into communication with the outer world, which receive impressions from the outer world (impressions which are, if you like, caused by contact of some kind or other with the outer world), and from which those stimuli are conveyed, by means of nerves, to the great nervous centres, producing what we call sensations.

But before speaking of the organs of the special senses, I want to draw your attention to the fact, that there are certain general sensations that have no particular locality; for instance, we have the sensations of hunger, thirst, restlessness, fatigue, and a number of other sensations which depend on states of the nervous system, sensations that do not belong to any particular part of the body, general sensations. Then there is the so-called muscular sense, which is localised in a special apparatus. People who are accustomed to deal with a particular kind of article are able, by taking up a certain quantity of it, to say very nearly its weight. That is due to a sense which has been called the muscular sense. I may make the matter simpler in this way. Suppose I put my hand on the table, and put this sheet of paper

on it, I can feel the paper on it; that is due to one of the special senses; but suppose I put on this piece of paper a weight, now I not only feel that there is something on my fingers, but I feel that there is something I have to resist, to hold up; and this sensation is due to the muscular sense, by means of which we are able to judge of weights.

We will now pass on to the five special senses.

There is one of these special senses, and only one, which is not confined to the head. The sense of *touch* is possessed by the skin all over the body, so you see that the skin is not merely a great excreting organ, nor merely a covering which protects the softer organs beneath it, but is an important organ of special sense.

Now, in the skin, in the papillæ of the skin, the elevations that are found on the surface of the true skin, underneath the scarf-skin or epidermis, the ends of the sensory fibres of the spinal nerves are found; these sensory fibres end in various ways in the papillæ; and in the parts which are specially endowed with what we call tactile sensibility (as, for instance, the tips of the fingers), they end in little spindle-shaped bodies which are called tactile corpuscles.

I want you to see how this apparatus acts. When we touch an object we touch it with part of our skin, and not with the ends of the sensory nerve fibres which belong to that part of the skin.

That is an exceedingly important thing to bear in mind; we touch an object with the epidermis, or scarf-skin that is in contact with the papillæ beneath, in

which these sensory fibres end. When we touch an object the extremities of the nerves are not brought into contact with the object; and we shall find that this is true of all the organs of special sense; that the stimulus from the external world is not applied directly to the nerve itself, but to some modification of the epidermis or epithelium. If we lay bare some part of the skin, and the extremities of the sensory fibres of the nerves touch the objects, we do not get in our brain the sensation of touch, but that of pain. If we irritate in any way directly the sensory fibres of the nerves, we do not get the special sensation that these nerves ordinarily convey, but we get a sensation of pain.

Those nerves that belong to the sense of touch also convey other sensations of a somewhat different character—the sensations of heat, cold, etc.; and the same thing is true of these also, if we apply the exposed ends of the sensory fibres of the nerves to heat or cold, we do not get the sensation of heat or cold, but the sensation of extreme pain; and the sensation is precisely the same whether we put them against an extremely hot or an extremely cold object. Persons who touch an extremely cold object, and do not know what they are touching, think it is red hot.

Now, the sense of touch is not equally developed all over the different parts of the body; it is extremely developed, as you would expect, at the ends of the fingers, where the tactile corpuscles are very numerous. If you take a pair of compasses, and put their points a tenth or a twelfth of an inch apart, and touch

the tip of your finger with them, you will feel the points of these compasses as two. If, on the other hand, you put them against the cheek, with the legs of the compasses half-an-inch apart, you will find that the two points feel like one, because the sense of touch in the skin of the cheek is developed to a much less extent than it is at the tips of the fingers. Similarly, if you put the compasses on the skin of the back of a person, with the points as much as 2½ inches apart, even then the two points cannot be distinguished from one another; so that, you see, the sense of touch is not equally developed all over the body. Although the skin of the body is an organ of special sense, the organ of touch, and although that sense is developed all over the body, it seems as if the sensory nerve fibres in different parts of the skin do duty for a much larger area of the skin in one part than in another.

Let us pass on from the sense of touch to the two senses that are very nearly akin to it—the senses of taste and of smell. The sense of *taste* is, indeed, a very slight modification of the sense of touch. On the surface of the tongue, the special organ of this sense, there are a large number of papillæ of three different kinds, many of them so large that you can see them perfectly well by putting your tongue out before a looking-glass. In these papillæ, just as in the papillæ of the true skin all over the body, the fibres of the two sensory nerves that belong to the special sense of taste end; and they are not exposed on the surface of the mucous membrane covering the tongue; their ends are in these papillæ, which

are covered by the epithelium, the fine membrane which covers all the internal organs of the body that communicate with the external air. They are covered with the epithelium just as the papillæ of the true skin are covered with the epidermis or scarf-skin; and so, the objects that are tasted stimulate these nerves to convey certain sensations to the brain, which the brain interprets as taste; these objects do not touch the extremities of the nerves.

Now, as to the sense of *smell*,—

You will remember that I told you in the last lecture, that of the twelve pairs of cranial nerves that leave the brain the first pair are devoted to the sense of smell, and have no other office to perform.

These nerves lie along the upper surface of one of the bones of which the skull is made up, which bone is pierced with a large number of small holes; branches from the nerves pass through these small holes down into the upper part of the cavities of the nose, and they are distributed to the mucous membrane which lines those upper cavities.

I told you, when speaking about breathing, that the breathing or respiratory passage passed through the nostrils along the lower part of the cavities of the nose into the cavity at the back of the mouth, which we call the pharynx. The nerves which belong to the special sense of smell are, then, distributed to the mucous membrane of cavities which are in close connection with the respiratory passages in the nose, being, in fact, just above them and communicating directly with them,

and as the bodies that are capable of exciting the sense of smell come to us in the air that we breathe, you will see that that is precisely the position in which you would expect the extremities of those nerves to be placed.

As the air passes along the lower cavities of the nose some small quantity of it gets into the upper cavities; if the air that we breathe contains a considerable quantity of particles that are capable of exciting these nerves, they convey to the brain the sensation of smell. If, for instance, the air is loaded with attar of roses, then as it passes along the respiratory passage sufficient particles of that scent will get into the upper cavities of the nose, and will stimulate the extremities of those nerves through the epithelium which covers them. If the air is only lightly charged with particles, we draw air forcibly into the nose, so that more of it than usual gets into the upper cavities of the nose, and brings the particles that are capable of irritating the nerves of smell into contact with the mucous membrane; but mind the extremities of these nerves are not directly exposed to the particles which produce the sensations of smell; the extremities of these nerves end in mucous membrane, which is covered by the epithelium, and when substances are brought into the nose that are capable of destroying the epithelium, such as strong acid vapours, they do not produce a sensation of smell, but one of pain.

Now you see in these senses that I have described we have had direct contact of the sensory apparatus with external *objects*.

But the organs of the other two senses are contrivances for taking note of certain kinds of *movements* which occur outside of us, and enabling such movements to produce stimuli which travel to the brain along the nerves which belong to the senses of sight and hearing.

We will take the sense of *sight* first, because it is one easily understood, and most interesting. The organs of the sense of sight are two bodies which are nearly but not quite globular, composed, in fact, each of portions of two spheroids, and they are situated in cavities which are called orbits, which are walled, as it were, by bones belonging to the skull and face. These cavities, of course, are open in front, and have each an aperture at the back of them, through which the nerve which goes to the eye from the brain passes—the nerve which I mentioned in the last lecture as the nerve belonging to the second pair of nerves—the optic nerves.

The eyeball is protected by means of the bony walls of the cavity in which it is placed, and by the arched projection of part of the frontal bone ; it is protected by the covering of the latter with fat, skin, muscle, and even hair in the eyebrows ; it is protected by fat at the back, and by muscles which surround it, and by means of which it is moved ; it is protected in front by two lids, partly composed of tough cartilaginous substance, partly composed of muscle and skin ; and, again, it is still further protected by the fringes of hair which we call the eyelashes. This is, roughly speaking, the way in which the organ of sight is protected from injury by ex-

ternal violence. The eyeball itself consists of certain layers or coats on the outside, enclosing a cavity which is divided into two, as will be described presently. The greater part of it is invested with a tough, whitish, opaque, hard, coat, which is called, from its hardness, the *sclerotic* coat. This coat has an aperture at the back, through which the optic nerve passes into the interior of the eyeball, and is in continuation with the fibrous sheath of that nerve. This coat does not extend over the whole eyeball, but in the front part it is replaced by a transparent substance or coat, which is called the *cornea.* Inside the sclerotic there is a finer coat which is very largely supplied with blood-vessels, and which contains several layers of dark-coloured pigment; in this coat travel blood-vessels, by means of which the greater part of the structures in the eyeball are nourished, and also important nerves which go to the front part of the eyeball, and that coat goes by the name of the *choroid* coat. It, as it were, lines the hard outside coat, or the sclerotic coat, and at the front part, very nearly where the opaque sclerotic coat joins the transparent cornea, the choroid coat divides into two parts, one of which ends in a kind of fringe, while the other is continuous with a curtain placed a short distance behind the cornea: this curtain goes by the name of the *iris*, and has in the middle a circular aperture called the *pupil.* The iris is largely supplied with blood-vessels and with nerves, and it contains muscular fibres within it. How that acts, and what are its uses, I shall describe in a few minutes.

Inside the choroid coat we find a thin white film, which is continuous with the optic nerve. The optic nerve passes through the hard sclerotic coat on the outside, passes through the coat containing blood-vessels and pigment, called the choroid coat, and then it is expanded, and its fibres are distributed in this fine white structure, which goes by the name of the *retina*, and which lines the inner surface of the choroid membrane pretty nearly up to the place at which the sclerotic coat joins the cornea. These are the coats, then, roughly described, which surround the remaining structures that are inside the eyeball.

Pretty nearly opposite the place where the white part of the outside coat of the eye joins the transparent part, there is fixed a transparent body, which we call the *crystalline lens*—shaped like what we ordinarily understand by a lens, a body which is convex on both sides. This divides the cavity of the eyeball into two—the front cavity between it and the cornea, and the posterior cavity between it and the retina. The front cavity is filled with a watery fluid, which goes by the name of the aqueous humour, and the posterior cavity with a gelatinous body, which goes by the name of the vitreous humour.

I will go on to describe the way in which this apparatus works, and I will explain a little more at length the structure of the sensitive part of it, viz., the retina.

When rays of light fall upon what we call a lens of glass, or of any transparent substance denser than air, which is convex on both sides, if they are parallel to

one another like the rays of light that come from the sun, after they have passed through this transparent substance they are no longer parallel to one another, but are brought, for reasons I have not time to describe, into a point; that point is called the focus of the lens, and the distance of that point from the centre of the lens is called the focal length of the lens. When the rays of light proceeding from an object on one side of a convex lens, and passing through it to the other side of that convex lens, are received on a screen placed at a certain distance from it, these rays of light form an image of the object on the screen on the other side of that lens. The rays of light from the upper part of the object that pass through the centre of the lens, necessarily fall upon the lower part of the screen, and those which start from the lower part of the object, and pass through the centre of the lens, fall upon the upper part of the screen; as the rays which pass through the centre of the lens are most concerned in the production of the image on the screen, this is consequently upside down.

Now, in the eye we have a series of lenses. The transparent cornea is a lens, the aqueous humour is a lens, the crystalline lens is another, and the vitreous body is a lens; so that we have a series of lenses which we may call a compound lens, but, for the sake of simplicity, we must consider the action of the most important of them—the crystalline lens. From what I have said, you will see that the image of an object placed in front of the eye must be produced by this crystalline lens somewhere behind it, upside down, and

if there is a curtain placed behind that crystalline lens, so that the image of the object in front can be produced upon that curtain, it will be produced there upside down. There is such a curtain, and that curtain is the inner coat of the eyeball, which we call the retina.

In the retina there are several structures, the most superficial consisting of the expansion of fibres of the optic nerve; there are other structures below that, and the deepest structure in the retina, next to the choroid membrane, is a layer, called, from the shape of the structures in it, the layer of rods and cones.

When, then, an external object is placed in front of the eye, its image is produced upside down upon the retina, distinctly if the latter is at a proper distance, if not, the image is still produced upon it, but indistinctly.

In this retina there are two spots, the structure of which differs from the structure of the rest of the retina. One of these is the place where the optic nerve goes in. The optic nerve does not enter the eyeball in the centre of the back of it, so to speak, or in what is called the axis of the eyeball, but at a point a little nearer to the nose. Now the point where that nerve enters is one of the peculiar spots in the retina, and the other is immediately opposite the axis of the eyeball.

When an image is produced upon the retina, a stimulus is caused which travels along the nerve fibres of the optic nerve to the brain, and produces the sensation of sight. Where is that stimulus started?

The nerve fibres of the optic nerve are spread upon

the surface of the retina, and is it the nerve fibres of the optic nerve that are sensitive to the light? if so, the sense of sight differs in a remarkable manner from the three senses already described. Nothing of the kind; the spot in the retina which is most sensitive to the action of light is the spot called the yellow spot, which is in the axis of the eyeball. In that yellow spot there are no nerve fibres at all, but on the other hand the layer of cones is highly developed. The most sensitive part of the retina, then, contains no nerve fibres at all. I said that the spot at which the optic nerve enters is another peculiar spot: there you have nothing but nerve fibres, the other coats of the retina are not developed at all. The nerve fibres of the optic nerve pass through the sclerotic and choroid coats, and then spread abroad on the inner surface of the rest of the retina, so that there is nothing but fibres where the optic nerve enters the retina; and the spot where the optic nerve enters is blind, so that the place where there are most nerve fibres is insensitive to light; you can prove it. If you take a piece of paper, and make two marks upon it, three or four inches apart, and look with your right eye fixedly at the left-hand mark, placing the latter directly in front of the eye, shut the left eye, and then move your head towards and from the paper; in a little time you will find that in a certain position you can see the left-hand spot, but you cannot see the other; you will find that there is a certain position in which you can see one spot distinctly, but if you move your head either way, you can see both spots. Now, it

has been shown by accurate experiment, that when that is the case, the image of the other spot is produced upon the place where the optic nerve enters the eyeball.

I say that the place where the optic nerve enters the eyeball, where there are most nerve fibres, is blind, so we see that it is not nerve fibres that are affected by the stimulus of light; the layer of cones is, in fact, the part of the retina which is sensitive to light, and from it stimuli are conveyed along the nerve fibres from the retina to the brain, so that in the sense of sight, just as in the senses of taste and smell, the stimulus is given not directly to the nerve fibres at all, but to another structure altogether.

In the case of light, what movements are transferred in this way into stimuli in the optic nerve? Movements occurring in a very attenuated medium called ether, which permeates all space and all bodies. It is by movements of the particles of this ether that the stimulus is produced which gives us the sensation of sight.

The eye is an optical instrument, and it has certain arrangements which we find it well to imitate, as far as we can, in all our best optical instruments.

You will remember I told you that in the choroid membrane and in the iris, there are not merely blood-vessels and nerves, but layers of pigment. Now, what are those layers of paint for? They have several uses; one of them is to absorb the rays of light which would, for one reason or another, interfere with the distinctness of the image that has to be produced on the retina.

Dark substances absorb light, and one of the reasons of the existence of colour in the eye is, that rays of light, which would otherwise be of no use, and not only be of no use, but be of harm, shall be absorbed. It is not the only use, but it is the only use I need mention here.

Why, you will say, is the iris placed in front of the crystalline lens? Why are not all rays of light that fall upon the cornea allowed to go into the eye? That curtain cuts off a great deal of the light that would otherwise fall on the crystalline lens, and pass into the eye. A distinct image of a body placed in front of the lens is made by rays that pass as nearly as possible through the centre of the lens, as the rays of light that pass from a body through the edges of a lens only serve to blur the effect; and so it is desirable, in constructing optical instruments, that means should be taken for ensuring the entrance of rays chiefly through the middle of the lenses; that is, then, the reason of the existence of this iris. In a telescope or microscope you will see at certain distances discs, with holes in their centre, called diaphragms; they prevent rays passing through the instrument otherwise than through the centre of the lenses; they are blackened, and the interior of the instrument is also blackened, in order to absorb all the rays of light, except those that pass through the middle of the lenses, and to prevent their being reflected from side to side, so as to cause confusion. The iris, then, is the diaphragm of the eye.

Now, I said that in this iris there were muscular

fibres; these are of two kinds: there are muscular fibres that run round the aperture; circular fibres, that are supplied with nerves from the third pair of nerves, the nerves which supply most of the muscles connected with the eye; and there are fibres that run from these circular fibres towards the outside of the iris, radiating fibres, which are supplied by branches from the great sympathetic system of nerves. When the circular fibres contract, they make the aperture smaller, and so shut out a certain quantity of light. When the radiating fibres contract they pull the circular band around the pupil outwards in all directions, because the iris is fixed round its edge, and so make the pupil larger. When do these contract? When too strong a light strikes upon the eye, and passes through the crystalline lens on to the retina, a reflex action occurs; the too strong light causes a great stimulus, which is transferred along the fibres of the optic nerve to the ganglia at the base of the brain; they then start another stimulus, quite independently of the will, which passes along the third pair of nerves, and causes that circular muscle round the pupil to contract, and make the pupil smaller, so that less light can penetrate into the eye.

When, on the other hand, you go into a dark room where the light is not sufficient for you to see, a command is sent along the sympathetic nerve, which is the nerve which stimulates most of the involuntary muscles of the body to act, to the radiating fibres for them to contract and enlarge the pupil, so as to admit more light into the eye. The iris is thus a self-acting dia-

phragm; if there is too much light, it partially shuts up the aperture; if too little, it expands the pupil, so as to admit more.

Now, we are able to see objects at different distances quite clearly, and that is done by a self-acting adjustment, by means of which the shape of the lens, which is elastic, is altered, so that we can, if we look at an object close to us, have an image produced quite clearly upon the retina, and transferred from that to the brain; and the same is true if we look at a distant object.

Suppose that the image of an object, instead of being produced upon the retina, is produced in front of the retina, then an indistinct image of the object is produced upon the retina. The rays of light are in that case brought to a focus too soon, or short of the retina, and the person is said to be short-sighted. Suppose, on the other hand, that the rays of light from the object would be brought to a focus, so as to produce a clear image behind the retina, they then form an indistinct image upon the retina, and you have what is called weak sight. In short-sighted people the rays of light are brought to a focus in front of the retina, and in weak-sighted persons (especially in old people) the focus is behind the retina, so that in the one case glasses are worn to prevent the rays of light coming to a focus too soon, and in the other to make them come to a focus quicker. Now, it is quite clear that a doubly convex glass would not do the former, so a kind of lens is worn by short-sighted persons which is concave on both sides, and that glass has the property, instead of bring-

ing the rays of light together, of diverging or separating them to a certain extent, so that they do not come to a focus so soon; and weak-sighted persons have to wear doubly convex glasses which will bring the rays of light together sooner.

What have we two eyes for? Why will not one eye do? Well, it is astonishing what people having but one eye are able to do with it, but that is a matter of great practice. Having two eyes, we are able to judge distances, and we judge the distance of an object partly by our knowledge of its real size, and partly by an involuntary estimation of the angle between the optic axes, when both eyes are directed towards the object; and we are able also, by means of our two eyes, to see bodies stereoscopically; to tell, for instance, whether their surface is concave or convex.

When I look at this bottle the image on the retina of my right eye includes more of the right hand side of the bottle, and that formed on the retina of my left eye includes more of the other side; so that between these images, which are different in the two eyes, I am able to understand that the bottle has a convex surface.

How is it that if the images are produced at the back of our eyes upside down, we see things as they are? There have been a lot of ingenious theories to explain this; one was that it had something to do with the junction of the optic nerves; but it is the simplest possible thing in the world, a pure matter of experience. We are accustomed, from our earliest infancy, to regard images that are produced on the lower part of the retina

as coming from objects high up, and we are accustomed to regard images produced on the upper part of the retina as coming from bodies low down; and so, when we have an upside down image produced upon the retina, we see it the right way up, because the lower part corresponds, and the upper part corresponds with the whole experience of our lives.

The eyeball is moved in its cavity or orbit by four muscles called the recti, or straight muscles, which are attached to the sclerotic coat, and, passing backwards, are fixed to the bones at the hinder part of the orbit; a superior one above and an inferior one below, an external one outside and an internal one inside. When the upper one contracts it makes the eye look up, when the lower one contracts it makes the eye look down, when the external one contracts it makes the eye look outwards, and when the internal one contracts it makes the eye look towards the nose. There are two others; they start on the outer side of the eyeball, one above and one below. They are called the oblique muscles. One of these, the upper one (the superior oblique muscle) starts on the outer side, its tendon passing round a little notch in the bone, which forms a kind of pulley, and then it lies back along with the straight muscles. The inferior oblique muscle is attached below to the outer side of the eyeball, and by its other end to the floor of the orbit. When either of these contracts it pulls the eye round, so that between these six muscles the eye can be turned in all directions, and they are supplied by the nerves named in the last lecture.

The eyelids are lined by a mucous membrane which we call the *conjunctiva,* which secretes fluid which continually moistens the front part of the eye. That mucous membrane is not continued over the transparent cornea, but only its epithelial lining. The eye is kept still moister by means of the secretion of a gland on the upper side of the eyeball, called the lachrymal gland or tear gland, which secretes watery fluid continually, keeping the front part of the eyeball moist. The excess of fluid is conveyed by some small ducts into a tube which leads into the nose, and which is a kind of drainage tube for the eye-socket. When that secretion is excessive, that drainage tube is not able to carry it all off, and it rolls out on to the surface of the face in the form of tears.

The colour of the eye, as we call it, is due to the colour of the iris. That colour is caused by the pigment in the iris and by the blood in the blood-vessels of the iris, and in that way we get all the varieties of black, grey, blue, brown, etc. that we see in people's eyes. Persons who have no pigment in their eyes and no pigment in their hair are called albinos, and they have pink eyes, the pink colour being due to the colour of the blood in the iris.

Such persons always have weak eyes, and can only bear a very small amount of light, and that shows you that one of the principal objects of the pigment in the iris and in the choroid membrane, but especially of the pigment in the iris, is to absorb light which is not required for the purposes of clear vision.

The *organ of hearing* consists of three parts—the external ear, the middle ear, and the internal ear, the two latter being contained in cavities in the hard part of the temporal bone. The external ear is more or less trumpet-shaped, and has a passage leading through a hole in the temporal bone to the middle ear. Across the end of this passage, separating the external ear from the middle ear, is stretched a membrane called the *tympanic membrane.*

The cavity of the middle ear, on the inner side of this membrane, is called the tympanum, or drum of the ear, and communicates with the pharynx by a tube called the Eustachian tube. On the inner side of this cavity, opposite to the tympanic membrane, are two openings in the bone closed by membranes which form separations between the middle and the internal ear. A chain of three small bones jointed together stretches between the tympanic membrane, to which the first of them is attached, and the membrane closing one of these two apertures on the other side of the tympanum, to which the third bone is attached. The internal ear or labyrinth is contained in complicated cavities in the bone, called the vestibule, the semicircular canals, and the cochlea (or shell, from its shape). Inside these cavities is a closed sac, prolongations from which extend through the winding passages of the bone. Outside of this sac, between it and the walls of the cavities, is a watery liquid called *perilymph,* and inside of the sac is a liquid called *endolymph.* On the inner wall of the sac, and, therefore, in the endolymph, there are in some

parts fine hair-like bodies, and in others small calcareous particles, looking something like grains of sand, or little rod-like bodies placed side by side like the keys of a pianoforte (called fibres of Corti). The fibres of the seventh pair of cranial nerves—the auditory nerves—are distributed to the walls of the membranous labyrinth, as this complicated sac is called, and their extremities are in connection with the little bodies just mentioned.

When the waves of sound, caused by vibrations of the particles of the ear, being collected by the external air and directed along the passage leading towards the middle ear strike the tympanic membrane or drum, it vibrates, and its vibrations shake the little chain of bones that cross the cavity of the middle ear, and so shake the membrane closing the aperture on the other side of the tympanum to which the last bone of the chain is attached. At the same time the vibrations of the air in the tympanum cause the membrane covering the other aperture leading into the internal ear to vibrate.

The vibration of these two membranes sets the perilymph in motion, and its vibrations are transmitted to the walls of the sac or membranous labyrinth in the internal ear, and so the little hair-like bodies, calcareous particles, and fibres of Corti are shaken, and their movement irritates the extremities of the auditory nerves, by the fibres of which the stimuli produced are transmitted to the brain.

No doubt the different parts of the labyrinth have different duties to perform. One part, for instance, has

to do with the quantity or loudness of sounds, another with the quality or tone; but what I want you specially to note is, that the extremities of the optic nerve are not themselves directly affected by the vibrations of the air, but that, as in the case of the other senses, the stimulus which comes from outside the body affects a structure belonging to the epithelial tissues.

LECTURE VIII.

THE HEALTH OF THE INDIVIDUAL.

THE causes of disease have been studied from the very earliest times; the earliest writers on medicine wrote far more about the laws of health than they wrote about medicine. Hippocrates, the celebrated father of medicine, wrote far more about the health of the people, and the prevention of disease, than he did about the cure of disease. He wrote, for instance, works about Foods, about Diet in acute diseases, about the use of Liquids, and his celebrated work about Air, Water, and Places. You see merely from the titles of these works that they more concern the preservation of health and the prevention of disease than medicine proper or the cure of disease, and the great physicians who followed Hippocrates followed his example in this respect.

Now, at the very outset of the subject, we come across certain terms, that are well known to us, that are household words, but which we require to understand more definitely before we can go on to anything else.

We talk about a person's constitution; what do we mean by a person's constitution? We say a person has a strong constitution or a weak constitution; what do

we mean by it? A person has a strong constitution when he has no tendency to, and no sign of, disease. A person has a weak constitution when he has a marked tendency to disease of any kind; one marked tendency to disease of any kind is sufficient. Constitution has been defined as the resultant of the physiological forces of the body. But if any one of these forces tends in the wrong direction, the person has no longer a strong constitution. These forces are very many; one of the most important of them is hereditary tendency. If a person, by hereditary tendency, is liable to a particular kind of disease, that person cannot be said to have a strong constitution. We do not speak of a person that is liable to consumption for instance, one who belongs to a consumptive family, as having a strong constitution; he has a hereditary tendency to that disease. And so the capacity of the lungs, the power of the heart, or, if you like, the power of the circulation, the power of digestion, and a large number of other physiological forces—if I may so use the term—are elements in our constitution; they are the forces from which the resultant, which is our constitution, is made up; but it must be remembered that any one of these forces being weak, or tending in the wrong direction, towards disease rather than health, makes us have a weak constitution instead of a strong one.

Now, persons who originally had a strong constitution, by virtue of their good hereditary tendencies, may turn it into a weak one by following habits of one kind or another, by excesses of one kind or another, originat-

ing in that way a tendency to disease, or actually developing diseases of one kind or another, so that persons having originally strong constitutions may ruin them, as it is called.

After dividing people into those who have strong constitutions and those who have weak constitutions, the ancient physicians, with Galen at their head, pointed out that healthy people might be divided into classes according to certain marked characteristics; one healthy person is quite different from another healthy person, and so persons have been classified according to what are called their *temperaments*. By temperament we mean the predominance of one of the general systems of the body over the rest; for instance, the circulatory system. Some people have a very powerful circulation, strong hearts, an abundance of rich blood, organs well nourished, well developed; they are not readily attacked by disease, and when attacked they very speedily get well; these persons are said to be of the *sanguine* temperament. Next we have the *lymphatic* temperament, in which the absorbent system has undue predominance over the other systems. These persons are described generally as of unsymmetrical build, with a pale, flabby complexion, not florid like persons of the sanguine temperament. Persons of this temperament are found especially in damp unhealthy localities, where they are crowded together, and neither take sufficient exercise nor have a sufficient amount of good food: they are subject to diseases known as scrofulous diseases, which attack

the bones and lymphatic glands, and cause those marks that you often see in the necks of unhealthy children. Now this temperament requires to be combated by attention to hygienic conditions, especially attention to conditions of place of residence and to eating and drinking. When this temperament is strongly developed it must not be considered as a condition of health, but as a condition of disease, and persons in this condition have descended from persons subject to scrofulous diseases. There is a third temperament, of which most of you have heard—viz., the *nervous* temperament: in this the nervous system has undue predominance over the other systems. There are an immense number of people who are working their nervous system to a much greater extent than it should be worked; in these people the tendency to over-work, over-excitement, and worry gets worse and worse, and it has long been pointed out by physicians that persons who belong to this nervous temperament in a marked degree have the tendency to get worse and not to get better. And on this I ought to insist a little more, because this temperament is most marked in our time: in these days of express trains and telegraphic messages everything goes on so fast, and the competition of life is so great, that the tendency of the great majority of people is to over-work themselves mentally, and to over-worry themselves about big and little cares. When this once begins, it goes on getting worse. This nervous temperament is associated with nervous diseases, and it has long been observed that persons of a distinctly

marked nervous temperament belong to families in which nervous diseases are prevalent, and so it is of the greatest importance for persons who have a tendency to this state of over mental work and excitement to be on their guard against either over-working themselves or over-exciting themselves, and it is perhaps of still greater importance that persons should be on their guard against over-working children who are willing to work. The difference between a child of the nervous temperament and a child who belongs to the lymphatic temperament is extremely marked; and it is of the greatest importance for people who have the training of children to take note of this from the beginning, and rather to check the tendency to over-work of the nervous excitable child, and to stimulate the sluggish, drowsy, lymphatic child. The reverse is commonly the case; and children of the nervous temperament, who would do quite enough or too much work if left alone, are excited to over-work and competition of all kinds to gain prizes, instead of being rather held back on account of their excitable natures and too irritable nervous systems.

These are the three chief temperaments of the ancient writers, but another, called the *bilious* temperament, is often mentioned. This, however, we do not now consider a temperament, because it is not due to a predominance of one of the general systems of the body.

The great mass of human beings do not belong markedly to any one or other of these temperaments, and so persons who insist upon the division have invented the *mixed* temperaments.

Celsus pointed out that human beings, after being divided into these large classes according to their temperaments, might be divided into much smaller ones. He taught that each human being had what he called his weak point, of which he had to take special care, in order that he might ward off the diseases to which he himself was more specially liable than the people around him. These minor divisions are called *idiosyncrasies*. An idiosyncrasy is a tendency to excess or defect in any given limited direction, a peculiarity in the action of any particular organ of the body, or particular apparatus of the economy. They are of very various kinds, some of them apparently very unimportant; but those that are unimportant form illustrations, and explain to us and make us better understand those that are of great importance. Now, there are idiosyncrasies (to take some of the comparatively unimportant first, in order that you may quite understand what I mean) of the organs of the senses. Some people there are who cannot bear the taste of strawberries; that is an example of an idiosyncrasy, and a very peculiar one.

There are plenty of instances of persons who cannot sit at a dinner-table when certain things are on the table; for instance, a leg of mutton. Now, these are idiosyncrasies of taste and smell.

Now, to pass on to idiosyncrasies which more immediately concern the subject in hand. Persons are liable, as Celsus pointed out, to particular diseases. One person is peculiarly liable to certain diseases to which another person next him may not be liable; and that

other person may be liable to diseases of another kind, and that is what Celsus meant to insist upon.

Several persons exposed to a draught may get very different diseases from it, if they get any; one person gets a sore throat, another person gets bronchitis, another a cold in the head, another quinsy. Why is that? That is because, as Celsus said, each person has his weak point, which is liable to be attacked whenever he is exposed to a cause of disease, and each person should take care to find out what is his particular weak point, in order that he may ward off the disease to which he is liable. His weak point very often has come to him by heredity; very often he has had an attack of disease for some reason or another which, in the first instance, we may not be able to explain. He has caught a very severe cold, and had some form of lung disease, and for the rest of his life he is more liable to an attack of disease in that part of the body than anywhere else. A person who has once had sore throat is more likely to have sore throat than he was before, so that you see idiosyncrasies may be acquired, may be formed.

A capital example of this is found in the case of a regiment of soldiers who encamp on marshy ground for a night; one of them gets ague of one form or another, another one gets a cold in the head, another rheumatic fever, another is subject to chronic rheumatism, and gets an attack of "rheumatics," another gets inflammation of the lungs, another bronchitis, another pleurisy, another a sore throat, another toothache, and another

gets nothing at all. Well, all these people get these different diseases from the same cause, from exposure to damp atmosphere, because they were weak in different points, because they had different idiosyncrasies. I say, then, it is of the first importance for everybody to find out what is the point about his own system which is most likely to be attacked, and take precautions against it.

Certain diseases, or tendencies to disease, are inherited. Why do we inherit a tendency to disease? We are not at all surprised if a son or a daughter is like either his or her father, or mother, or grandfather, or grandmother in the face; then, why should we be astonished that they are like them in the lungs or liver? If they are like them in external features, why should they not be like them in the construction of their internal organs? It is clear enough there is no reason why it should not be so, and it is the case; and not only do likenesses of that kind descend in families, but peculiar construction of organs descend, peculiar construction of features descend, and not only so, but incidental peculiarities descend.

There are plenty of instances where peculiarities have descended in families, where, for instance, a person has had six fingers on one hand, and the same peculiarity has occurred in his descendants. A notable example is that of the short-legged sheep, which were produced by a farmer in North America some years ago, who found accidentally that one of his sheep had got the two fore-legs short. That was an accident, or a

monstrosity of nature, and it occurred to this farmer that it would be very useful if he could get the rest of his sheep so, because he need not have his hedges so high; and so, by careful selection of the young ones, he produced a race of sheep which all had their fore-legs short. So you see that accidental peculiarities descend in families, and so it is that peculiarities in the construction of the internal organs of the body descend, and that tendencies to disease are hereditary. There are a few diseases that actually descend, in which the child is born in a state of disease.

One of the most marked examples of hereditary tendency to disease is found in consumption, the plague of our climate. This terrible disease kills more than half as many people as all the zymotic diseases (fevers, etc.) put together. There is no doubt that a tendency to consumption descends in families. I do not mean to say that consumption cannot start in any family. If you go and expose yourselves to the causes by which consumption is brought about, although there may be no tendency to consumption in your family, consumption may arise in you, and may be inherited from you. So, too, scrofulous diseases are hereditary.

Nervous diseases also run in families. Not that any one nervous disease necessarily descends in any family, but nervous diseases generally are hereditary. They are associated, as I told you just now, with the nervous temperament. Persons of such families, who do not actually suffer from nervous diseases, are very frequently of a marked nervous temperament.

These are some of the most common examples of hereditary diseases.

Now, what is to be done for hereditary disease? In the first, place it is clear that any one who belongs to a family in which one of these diseases is known to be hereditary, must do all he can to avoid the conditions which will favour the development of that disease. Persons who belong to families in which consumption or scrofula exists, must avoid living in damp houses, must avoid, as far as they can, inferior food and bad hygienic conditions generally. Persons who belong to families in which nervous diseases are prevalent, must avoid the conditions which I mentioned just now as conditions which should be avoided by persons belonging to the nervous temperament.

But the most important precaution of all is that persons who belong to families in which any kind of disease is hereditary, have no right to marry into families in which the same disease is prevalent. This is done continually, because people are thoughtless about this, one of the most important matters concerning them.

If there is any tendency to disease in your family, and you marry into a family in which that same disease exists, your children are almost certain to suffer from that disease in the worst possible form. If there is a tendency to nervous disease in your family, and you marry into a family in which nervous diseases are prevalent, it is very likely indeed that your descendants will furnish a very large number of inmates to the lunatic

asylums; people ought to think of these things a very great deal more than they do. Not only are tendencies to disease hereditary, but a tendency to long life is hereditary, and that you will see follows almost necessarily from what I have said. If mischief in the organs of the body is likely to descend, and if likenesses descend, it follows that perfection of the various organs of the body is transmitted in families, and so long life is hereditary. But there is another reason why long life is hereditary, and that is, that long-lived people have a kind of contempt for persons who are not long-lived, and they rarely marry into any families that are not long-lived families, and so this tendency to long life is increased, and that makes it still more markedly clear, and it has been observed over and over again that long life is hereditary.

That we are subject to different diseases, and to different kinds of disease, at different times of our lives, was pointed out by Hippocrates, who divided man's life into various periods, and showed that each period had its own diseases belonging to it. Now you will see at once that this must be so, when you consider how different we are at different periods of our lives. In a very young stage of life, for instance, there is no bone; it is only cartilage or membrane; as we go on getting older, bone becomes formed, bones become consolidated, some of them become soldered together, parts of the body become harder; and this process of hardening begins from the very beginning and goes on until we reach the most perfect state of our life, and while

it goes on to that state it is advantageous; we are getting our organs to work more and more in sympathy with one another, and their action is becoming more and more confirmed. Then for a long period we appear to be stationary, but we are not stationary at all; degeneration of tissue begins; some of our tissues are getting rather harder as time goes on, and we get gradually into the period of decay, the period of decline; some of the tissues get harder than they ought to be for the work they have to do; they get stiff, and calcareous matter gets deposited in various parts of the body when it ought not to be. The walls of the great arteries get less elastic and do not recoil upon the blood, the circulation becomes enfeebled, the tissues of the body have been gradually becoming degenerated, and so we pass on, until, if we are not taken off by disease of one kind or another, we die by the actual stoppage of one of the organs which is essential to our life, by the actual stoppage of our lungs or heart; so that you see, that at different periods of our life we are different beings altogether, and so it need not surprise anybody, that at those different periods of our life we are subject to different diseases. Now the periods of life have been divided differently by various authors; but the division which is the best, the division which we shall take, is the division given to us by that great observer of human nature, William Shakspeare. I do not know that it was really Shakspeare's, yet I do not know that it was not; it is generally put down to him. When looking into the question a short time ago, I came across a

quotation from a medical work of the time of Shakspeare, published in the same year as his "As You Like It," or a year before, in which the divisions of Shakspeare of the life of man are given, and in which a certain treatment for the different periods of life is prescribed; so that if it was not Shakspeare's division, it was a division which was suggested to him, and which he adopted.

Shakspeare, in his "As You Like It" (act ii. scene 7), makes Jacques say,—

> "All the world's a stage,
> And all the men and women merely players:
> They have their exits, and their entrances;
> And one man in his time plays many parts,
> His acts being seven ages. At first, the infant,
> Mewling and puking in the nurse's arms;
> And then the whining school-boy, with his satchel,
> And shining morning face, creeping like snail,
> Unwillingly to school. And then, the lover,
> Sighing like furnace, with a woeful ballad,
> Made to his mistress' eyebrow. Then a soldier,
> Full of strange oaths and bearded like the pard,
> Jealous in honour, sudden and quick in quarrel,
> Seeking the bubble reputation,
> Even in the cannon's mouth. And then, the justice,
> In fair round belly, with good capon lined,
> With eyes severe, and beard of formal cut,
> Full of wise saws and modern instances;
> And so he plays his part. The sixth age shifts,
> Into the lean and slipper'd pantaloon,
> With spectacles on nose and pouch on side,
> His youthful hose well saved, a world too wide
> For his shrunk shank; and his big manly voice,
> Turning again toward childish treble, pipes
> And whistles in his sound. Last scene of all

> That ends this strange eventful history,
> Is second childishness and mere oblivion,
> Sans teeth, sans eyes, sans taste, sans everything."

In infancy, the first great danger is from *external cold;* and why is that? Children, you say, have a quick circulation, quick respiration, all their actions go on quickly, a large amount of oxidation goes on in their blood, a great amount of animal heat is produced; how is it then that their great danger should be from external cold? Well, the reason is extremely simple. It is because they are small. And why is it because they are small that they are liable to danger from external cold? It is because their small bodies have large surfaces; a small body has a larger surface, in proportion to its bulk, than a large one. If you have a lump of lead, and were told to divide it so as to make the largest amount of surface, you would not divide it into cannon-balls or large bullets; but you would divide it into the finest dust-shot, and then you would get the largest surface; what is true of a cannon-ball is equally true of a baby. Suppose we take two solid bodies, a cube of one inch, and a cube of ten inches (see Figs. 1 and 2).

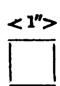

Fig. 1.

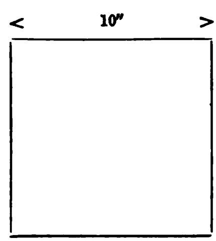

Fig. 2.

Now, the side of Fig. 1 is a square inch, and there are six sides; so that the surface of that is six square inches, and the contents one cubic inch; the surface of that cube is to the contents as 6 sq. in. to 1 cub. in.

Now, the side of Fig. 2 is 100 sq. in., and the surface of that cube is therefore 600 sq. in., while its contents are 1000 cub. in.: so that its surface is to its contents as 600 sq. in. : 1000 cub. in. = 6 sq. in. : 10 cub. in.

The surface of the small cube, then, is as 6 sq. in. : 1 cub. in., or as 60 sq. in. to 10 cub. in., and the surface of the large cube is as 6 sq. in. : 10 cub. in., so that the surface of the small one is ten times as great, in proportion to its contents, as the surface of the large one in proportion to its contents. What is true of a cube is true of a baby.

The surface of a child, then, bears to its bulk a much larger proportion than the surface of an adult bears to his bulk. What has that to do with it? From the surface of our body we lose heat. It is there that the perspiration is evaporated, and wherever evaporation goes on cold is caused, because heat is required for the process; so that the body which has the largest surface is likely to lose the largest amount of heat, because a large surface means a large evaporating surface, and that means a large cooling surface; and as a baby, by reason of its being small, has a very large surface compared with its bulk, it loses heat very fast; and so, although it is a machine which manufactures heat at greater speed than a grown-up person, still it loses heat at a much greater rate, and so the external

cold is mischievous to young children, and they must not be exposed to external cold or they will die, either from being frozen to death, that is to say, by the temperature of their blood being reduced below the point which is consistent with life, or by the chill on the surface producing partial stagnation of the blood in the internal organs, with resulting disease in certain important organs, especially in the lungs: and so young children in cold weather die especially of lung disease.

The next great danger to children arises from *improper feeding;* they are often given foods which they cannot digest, or they are not given enough to eat. The food provided by nature for children is the only food which it is proper for them to feed upon, viz., milk, and this is the only perfect food in existence, the only food which is capable of supporting an animal without any other food; it is through insufficient or improper nourishment that a very large number of children die, and it is one of the things of which we have most to be ashamed. There is no doubt that mothers ought to nurse their children, and it has been shown on a very large scale that the death-rate among children brought up in any other way is much greater than among children who are nursed by their own mothers. There is no doubt, therefore, that it is advantageous for the population that as many mothers as possible should nurse their own children, and I hope it will not become unfashionable in this country.

Now, the diseases that are caused to infants by giving them improper food instead of milk, starchy foods, meat, broths, and soups, which they are not a bit capable of digesting, are very many. In the first place, their digestive organs get out of order, and if they cannot digest their food it cannot be absorbed into their system, and their blood cannot be nourished, and a large number of the wasting diseases of infants are caused or accelerated by improper food. People have not the least idea of the mischief that indigestion does us from the beginning of our lives; they say a person *only* suffers from indigestion; "It is *only* indigestion!" but if you cannot digest your food, what do you expect you can do? Your body cannot be nourished, your brain cannot be nourished by your blood. Digestion is one of the most important things to pay attention to. So these children being fed on improper food, their digestion gets out of order and they suffer from diarrhœa, or, still worse, what is called the cholera of infants. When they so suffer, the first thing is to return to a milk diet; and if milk of an animal is to be given to them, it should be the richest possible cow's milk. I mean cow's milk with a considerable amount of cream—what is usually known and sold as nursery milk. Two parts of this should be mixed with one part of water, and sweetened with sugar. The milk diet, then, is the first thing, but some children suffering from wasting diseases of infancy cannot live upon this, they reject it; then it has been found that skim milk is far better for them. A Dutch physician a few years ago proposed that children who

could not digest milk should be given butter-milk, that is to say, milk from which all the fat has been removed, but which contains all the other constituents: the practice has been very successful, and a very large number of lives have been saved by giving children in this state butter-milk.

In mentioning foods that were not fit to give to infants, I mentioned starchy foods, and starchy foods, unless extremely well cooked, are positively indigestible. I mentioned also broths and soups, and so on. Some of you may be astonished to hear me mention these, but there can be no sort of doubt that infant stomachs are not capable, as a rule, of digesting meat, even in the form of beef-tea, broth, and soup, and that they are not capable of digesting animal food in any other form except milk, and if they are given these foods they get convulsions, get disorders of their digestion, and various other disturbances. In a large number of cases, infants who have convulsions get them through being fed on improper food—one of the last things that people look to.

In many cases of wasting disease, it has been found that one of the very last things you would expect, after what I have been saying, has been of the greatest benefit, viz. raw beef with the fat and fibrous tissue taken out carefully, and then the muscular part chopped up thoroughly until it is of the consistency of a thick syrup, so that it can be given with a spoon. It has often been found that infants will digest, and live upon this, and even get well, when nothing else seemed to do

them any good at all; and I can safely say that I have seen a larger number of lives of children suffering from severe diseases saved by this means than by any other that I know of.

Another thing that causes a great amount of mischief among infants in their digestion, is that they are fed too often; I do not mean that they are fed too much, because, as Hippocrates well said, "Children do not well support a fast." He was perfectly right; they are growing very quickly, their respiration and circulation are very quick, and they require a great amount of food; but a great amount of mischief is caused by feeding them too often. As a general rule, as soon as a child begins to squall out, something or another is stuffed down its throat by the fond mother or attentive nurse, but this is a mistaken practice. One of the most famous physicians in Europe, who has paid the greatest amount of attention to children's diseases, has laid down the rule that in the earliest part of infancy the child should be fed not oftener than once in every two hours, and that the intervals should gradually be lengthened to three hours; but that children ought not to be awakened to be fed. In that way they have time to digest the food which they take; but if the system of feeding them whenever they cry is resorted to, they soon get to know that whenever they want to be fed all they have to do is to cry out; they get fed irregularly, and soon suffer from indigestion.

No doubt the disturbance caused by teething often

upsets infants, but this is of small importance compared with errors in feeding.

Infants are especially affected by foul air, and a high children's death-rate is a sure sign of the general insanitary state of a place.

Where there is foul air in and about houses, you may be almost certain that there will be found a high children's death-rate.

There is a class of diseases that are especially prevalent during infancy and childhood,—I mean infectious or communicable fevers.

These diseases have certain peculiarities. I will not mention all of them, only two of the most important; one is that they are communicable from one person to another, and the other is that when a person has had one of these diseases he is not likely to have it again. Now, do not run away with the idea that he is certain not to have it again, for persons may have any one of these diseases twice, three times, or even more; and such persons, by the way, are admirable examples of idiosyncrasies.

A person who has had small-pox twice or three times must be said to have an idiosyncrasy, and such an idiosyncrasy may run in families. I once came across a family, and only once, in which all the members had had almost every kind of infectious disease, and several two or three times. This is a curious example of a very peculiar inherited idiosyncrasy; so you see that it is not impossible for a person to have one of these diseases more than once; but it is unlikely.

As I shall devote two lectures to the consideration of these diseases, I will merely tell you now that a child suffering from one of them should be kept apart from other children, and that it is necessary to have all children vaccinated before they are three months old.

LECTURE IX.

THE HEALTH OF THE INDIVIDUAL—*Continued.*

SCARLET FEVER is one of the diseases that are very prevalent among young children—a disease, like the rest of these infectious diseases, which spreads very readily in places where there is no through ventilation. It spreads, for instance, in houses built against a wall. It is a very common plan in building houses for workmen to set up a wall, and then build the houses back to back against this wall, and in houses built in this way infectious diseases spread with great rapidity. I have known scarlet fever spread all down one side of a street until it came to a cross street, where there was a current of air, beyond which it did not spread.

No one has ever, so far as I know, recommended that children should be deliberately exposed to scarlet fever (or scarlatina, which is the same thing), but this is often done with measles, and sometimes with whooping-cough. These are extremely infectious diseases, and especially diseases of childhood; diseases which do not kill many children directly, but kill large numbers indirectly by the colds that they catch while they are getting well; a large number of other children are injured for life or for many years. It is frequently

recommended to let children catch these diseases when they are prevalent in a mild form, in order that they may not have them later in life, for, if caught then, they are more or less dangerous. Still a large number of children do die of these diseases; they are especially diseases of childhood, and we are less likely to take them as we grow older. I think, therefore, that we should try and prevent them, just as we should try and prevent any other disease, and not allow anyone to get either of them if we possibly can prevent it. No one is ever rash enough to assert that children are better, and it cannot be denied that they are much the worse, in many instances, for having had one of these diseases. I think that it is far better not to expose children, but let them run their chance of never having these diseases at all.

Whooping-cough is so infectious that I believe it is of very little use to try to separate the children in one family. I believe that when it gets into a family the rest are almost sure to get it too, and that measures to prevent this are not of much avail.

Diphtheria is another infectious disease that belongs especially to childhood; it is frequently associated with scarlet fever, and is often traced to foul air. It is a very fatal disease.

Typhoid or enteric fever, although one of these communicable diseases, is not a disease that is prevalent among infants, for the simple reason that they are not so often exposed to its poison, except when their milk has been mixed with water containing the poison, and

when there have been so-called milk epidemics of typhoid fever, it has frequently been observed that infants took the disease, because the poison was given to them in the milk they drank, and it got into that milk from the water that was put into it, or, as it is said, from the water which was used to wash the cans in which the milk has been kept.

There is another disease which is very prevalent among infants, about which I will quote the words of Sir William Jenner:—

"First among preventible diseases I will place one, the mortality from which, in London at least, is so great as beyond question to swell largely the death-rate of children under two years of age, and yet one that has no place in the Registrar-General's returns; I mean rickets—the English disease, as it was formerly called. Not one child *ought* to die from rickets itself, and death from its consequences ought to be extremely rare; and yet the mortality from rickets, from diseases which would not occur but for the pre-existing rickets, and from diseases which would be trifling but for the co-existence of rickets, is enormous.

"The causes of rickets are—poorness of the mother's blood, errors in diet, *i.e.* feeding the child with food unsuited to its wants and to its digestive powers; and, as subsidiary causes, deficient light and impure air, produced especially by overcrowding of the sleeping-room.

"Poverty, inevitable poverty, plays a great part in the production of some of these causes. If society did its duty in providing suitable abodes for the poor, they

would suffer little from the want of light or overcrowding at night. The anæmia of the mother would be less, and her blood better fitted to nourish the infant. Ignorance of the proper mode of feeding the child assists in the production of rickets in a larger degree than poverty. Judging from my own experience, I should say that rickets so severe as to lead even indirectly to death would be comparatively rare did the poor know how to feed a young child—were the poor aware of the necessity of the infant being fed with food fitted to its age.

"Law can do something here; for it can make compulsory the teaching of the *practical* laws of health in all schools supported in any degree by the public money. To teach young girls how not to destroy their future children is surely as important as to teach them much of what is now considered essential for them to know. I would have an infant nursery attached to every national girls' school, so that the girls might be practically taught how to fulfil their practical duties to their family and to society.

"Diffusion of practical knowledge is the great preventive remedy of rickets. Law can aid in the spread of that knowledge; and society, if it did its duty, would remove the subsidiary causes of want of light and overcrowding. Inevitable poverty might possibly still keep rickets in a grave form among us; but were rickets kept within unpreventible limits the death rate of infants in London would be perceptibly diminished."

One other thing I have to mention, and that is, that all diseases due to damp, and especially diseases due to

marshy places, are particularly fatal to infants, and persons who are obliged to live and to work in marshy places should send their children somewhere else. That is one of the reasons why children are sent home from India by Europeans, who have to live there, as some of the most fatal marshy diseases are prevalent in that country.

From all I have said about children, you will see that I believe, and that those whom I have quoted believe, that they require a great deal of tact and care, and that the prevalent idea that children ought to be hardened by exposure to cold, etc., and by being given various kinds of food, and that they will thus be rendered stronger and more healthy during the rest of their lives, is quite an erroneous one.

Dr. Inman has put into very plain language his opinion of this method of treating children. If you coddle an infant and take care of it, it will very likely grow to be a strong healthy adult; but if you try and harden it by exposing it to cold, and by not clothing it properly, and in various other ways, you must not be surprised if you "soon have to measure it for a long box." That is a plain way of speaking which has rather gone out of fashion of late.

Let me enforce the importance of this by a tale. Once there was a very sickly, weakly, puny infant born, and the nurse who was present was sent off in a great hurry for a doctor, because the infant seemed so ill. She went, thinking that the infant would be dead before she could bring any doctor to see it. That infant was pro-

perly taken care of, and grew up to be Sir Isaac Newton. I leave you to imagine where the world would have been if that infant had been treated with the hardening method, which we all know is so prevalent now-a-days.

> Nature and nature's laws lay hid in night;
> God said, Let Newton be, and all was light.

We go on then: you must remember that we are dealing with the growing periods of life, and not only do the wastes of the body require to be replenished, but the body has to increase in weight, and so a good deal of food is required; and, like infants, young people require a good deal of food, and require food more often in the day than older people—four meals, or in some instances five, are certainly not too much for them—and they have to digest and absorb that food; and to do this their circulation and respiration have to be kept up to their proper degree of action; so they require a good deal of exercise, and exercise in the open air is one of the most important things for children. The degeneracy of the population of our large factory towns, which has been pointed out of late years, is chiefly due to the fact, in the first place, that infants are not properly fed, and, secondly, that the children do not have either a sufficient amount of food or a sufficient amount of exercise; they are employed too early at hard labour, and therefore grow up stunted.

A good deal of sleep is required by young children. Nine hours is commonly laid down by the best authors as the proper amount; and it is extremely important that their mental work should not be too prolonged.

They should have about the same amount of time for physical exercise as for mental work, and it should be divided during the day. The short-time system, which is gaining ground in so many schools now-a-days, is, I am quite sure, a correct principle. Children should not be kept hard at their studies for more than two hours at a time.

A great amount of mischief then, again, arises from the position that children assume when sitting; they are very apt to take up wrong positions, and so get curvature of the spine. A very important thing, too, which is often neglected in schools and offices, is the direction in which the light comes on to the tables or desks; when a child (or a grown-up person) is sitting at a table, the light should not come from the back, or else his shadow is on the paper, and he twists on one side, and so gradually gets curvature of the spine; the light should not come from the front, or else it is reflected by the paper into his eyes and dazzles him; it should not come from the right side, because it causes the shadow of his hand to fall on that part of the paper on which he is writing, but the light should come from the left-hand side. This appears a small matter, but it is an exceedingly important one, as it is connected, you see, with such a serious disease as curvature of the spine.

Infectious fevers are very prevalent in childhood. Typhoid fever is more prevalent than it was in infancy, and scrofulous diseases are very prevalent among children who live in bad hygienic conditions, as those who live in damp houses, or who are badly fed; and

especially among children who are descended from a scrofulous family.

Consumption is also prevalent, and more especially so where children live in overcrowded rooms.

During childhood the second set of teeth come out, and we have the same diseases due to dentition as when the first set were being cut—convulsions and general derangements and disturbances of the digestive system. While the second set of teeth are being cut very serious disturbances may occur to children's systems, and you must not be surprised if children are fretful and troublesome without any apparent cause at about five years of age, when their jaws contain both sets of teeth at once, with the exception of the wisdom teeth, when forty-eight teeth are growing in their jaws all at once. When you know the trouble of any little thing wrong with either of your teeth, you can easily imagine the trouble and pain it causes a child when twenty-eight permanent teeth are growing in the jaws, and displacing the twenty temporary ones.

At this time, too, the bad effects of rickets in infancy show themselves in a very marked degree. Rickets is a disease in which the bones are unable to take sufficient of the lime salts out of the blood, so that they are too soft, and one of the worst effects of this is, that when the external air presses upon the chest walls during expiration, and the lungs inside collapse, it bends the soft ribs, and so pushes the breast-bone forwards and makes the child pigeon-breasted, so that the lungs cannot expand as far as they did before; the heart is likewise impeded

in its action. You see, then, that rickets is a very serious disease, and its prevention of extreme importance. You must take the words of Sir William Jenner, that it is the first of many preventible diseases, and ought to be prevented. Another evil of rickets is, that the bones of the legs of ricketty children being soft, when they walk, which they are not inclined to do, the weight of their body is too much for the soft bones in the legs, and so you have crooked-legged children.

In youth, the third period, growth is still going on: a great deal more food is required then than later on in life, and much exercise is desirable. It is not necessary to warn great numbers of the youths of this country that exercise is necessary, for sometimes it would appear to be almost worshipped, but there are great masses of people in this country who do not take a right amount of exercise. Girls, as a rule, do not take anything like as much as they ought; it has become very much more prevalent in girls' schools to make them take more exercise, and it is a very good thing; but there are numbers of young people who are engaged many hours a day, not at work which requires much bodily exercise, but at work which is called sedentary work, sitting in offices and work-rooms, and they do not feel much inclined for exercise when the day's work is over, and very often, in the time that they might devote to exercise, do many other things which are not by any means advantageous to them. It ought to be impressed upon them that they are people who, at their time of life, require bodily exercise,—I mean bodily exer-

cise in which all their muscles are more or less brought into play. Walking to and from their business is all very well in its way, but it by no means exercises all the muscles of the body. There are plenty of exercises that can be got at a very little cost. Foremost are regular gymnastic exercises: by the regular practice of these all the muscles of the body are exerted in turn, and they have a great advantage in that a very short time is sufficient for them every day. Gymnastic exercises are not always or often performed in the open air,—that is one of their disadvantages,—but they are generally performed in well-ventilated rooms, which is the next best thing.

Another exercise which should be resorted to by a great many more than it is in the summer is swimming —an exercise by which almost all the muscles of the body are brought into play, and which is also beneficial from the point of view of cleanliness. And here I ought to say that youth is the time when habits of life are formed, and it is especially important that they should be formed in the right way; it is a time when such a habit as that of cleanliness, by which the action of the skin is promoted, should be formed, and when habits of attention to the action of the excretory organs of the body should be inculcated; because if the waste substances are not separated from the body as they are formed they will be re-absorbed into the blood, and will poison it; that poisoned blood will be distributed to the various tissues of the body, and I believe that we have no idea how many of the diseases of middle and

old age are due to the neglect of the proper action of the excretory organs.

After exercise there should be no fatigue felt for any length of time; if fatigue is felt for a long period after, it is a sign that either the exercise has been too violent or too prolonged; and that makes me remark that it is extremely important that exercise should not be taken too violently. It is necessary that there should be plenty; and, later on, much more violent and prolonged exercise can be taken with impunity than could have been taken during the period of growth.

Another habit that is sometimes formed during this period of youth is the habit of drinking alcoholic liquors. Now, whatever we may think, whether we agree with those who say that alcoholic liquors are injurious, or whether we are of opinion with Dr. Parkes, that we are not in a position to say that alcoholic liquors are altogether injurious, we must agree with the statement that the drinking of alcoholic liquors is extremely pernicious to young people—there are no two opinions upon that point; and, perhaps, a still more important thing is, that habits of this nature are very easily contracted, but very difficult to get rid of later on in life.

While I am discussing habits, I may mention smoking—a habit that, in this country at any rate, is, practically speaking, confined to one sex. Now, whatever we may think with regard to smoking, whether we think it altogether injurious, or whether we agree with a large number of people who think that, later in life, after the

fatigues of a day's mental and physical work, the soothing of a pipe or a cigar is a very pleasant and agreeable thing, and, on the whole advantageous, there are not two sides to the question when applied to growing people. Everybody agrees who has studied the subject at all, that for growing boys smoking is an unmixed evil, and that fact cannot be too widely known.

Consumption is the most fatal of all diseases during youth. I told you before that it is the plague of our climate, and it is especially so at this period of life. It is then it exerts the utmost fatal influence, and it is especially prevalent among young people who have to work either in trades where there is much dust in the air, or who have to work in close over-crowded rooms, where they breathe air over and over again. The trades in which consumption is especially prevalent are those in which there is much dust in the air, it does not matter what kind of dust; and there can be no doubt that a great deal of consumption among work-people would be prevented if they would take the precaution of wearing something to prevent the dust being drawn into the lungs. Several admirable things have been designed, and one of them has been designed by Professor Tyndall—a respirator, containing cotton-wool, which is capable of filtering off from the air that people breathe the dust that it contains, and there can be no manner of doubt whatever that if work-people could be induced to wear this, or something like it, they would be prevented, in many instances, from becoming consumptive. Many work-people are only persuaded with the greatest

difficulty to use anything that prevents their trade from being a dangerous and therefore a lucrative one; and a most notable example of this is the extreme difficulty there was in introducing the Davy safety-lamp.

At this time of life, too, anæmia, or bloodlessness, is particularly prevalent among those who work in over-crowded, close rooms, with many gas lights. It is especially prevalent among young girls who sit for a large number of hours together in such rooms, and the only cure for it is change of occupation; it is perfectly hopeless to do anything else.

Rheumatic fever is very prevalent among young people, from catching cold. This is a much more serious disease than is commonly thought, because it consists of inflammation of the fibrous tissues of the body, among which are the serous membranes of the joints, and among the serous membranes that are sometimes inflamed are the two that are inside and outside the heart — the endocardium and the pericardium; and when this happens it frequently causes a permanent alteration of the valves of the heart, so that those valves no longer act properly, and we have what is called valvular heart disease; this always gets worse, and cannot get better; it gets worse during the rest of life, and invariably shortens it, so that every possible precaution to prevent young people from getting rheumatic fever should be taken. It is not a communicable disease, like scarlet fever, whooping-cough, or measles, and has not the property of communicable diseases, that having had it once you cannot

take it again ; but, on the contrary, when you have had rheumatic fever once you are more likely to have it again, and if you do not get heart disease the first time you are very likely to get it the second time.

In manhood, the diseases we get are especially chronic diseases, and many of them result from having diseases in youth, for instance chronic rheumatism, and the most important thing during manhood is to take care not to eat too much food. In manhood, all that has to be replaced is the losses that are continually taking place ; there is no increase in weight, we remain stationary at the same weight, or about the same, for some years ; there are slight variations, but they are of no importance whatever ; any great variation from the ordinary weight during manhood is to be regarded suspiciously ; any great increase in weight shows that a man is either taking too much food or not enough exercise, or both ; and it should be remembered, in connection with this, that in manhood a man should not leave off his exercise ; he should take as much exercise as he finds, practically speaking, good for him, without tiring himself too much, or he will increase in weight, and begin to age sooner than he ought. On the other hand, any decrease in weight is to be regarded suspiciously, because it is likely to be the sign of some disease ; nevertheless, the variation of a few pounds either way is of no importance whatever.

At or before middle age the results of habits begin to show themselves, and the result of one habit, that of drinking alcoholic liquors, begins to show itself some-

times in a very marked manner. It is at this time that those persons who have been accustomed to drink small quantities of spirits during the day begin to find that they have something the matter with the liver; a man begins to find out that he has a liver, in fact. The fibrous structures of the liver are increased, they grow at the expense of the proper liver structure, and they compress it, and so press upon the small branches of the portal vein which brings the blood to the liver, and the blood is prevented from circulating through the liver in the way in which it ought to be circulated; it is resisted by the structure of the liver, and so the liquid part gets through the walls of the capillary vessels into the peritoneal sac—that sac which is folded in and about the organs of the abdomen—and the result is dropsy of the abdomen. Now, this particular kind of liver is quite easily distinguished, and is so thoroughly well recognised as being caused by drinking alcohol, that it goes among physicians by the name of the gin drinker's liver. The result of this disease is death, which is caused in several ways, sometimes by the fluid becoming so great in amount that it presses upon the diaphragm, impedes the action of the lungs and heart, and causes death, you may almost say, by suffocation. The habit of drinking spirituous liquors during life does not always result in this, but it often results in a bad form of indigestion. There are various reasons why the drinking of alcohol causes indigestion. I shall speak more about them when I come to speak about foods and drinks; but I want to point out here that we

pay much too little attention to indigestion, and the drinking of alcoholic liquors is certainly the first cause of indigestion. If our food be not properly digested it cannot be absorbed, the tissues of the body cannot be nourished, and they degenerate, so that alcohol causes degeneration of the tissues indirectly by causing indigestion, and causes degeneration directly by reason of its presence in the blood, and so spirit-drinkers, whether they have this liver disease or not, have degeneration of the various tissues of the body, and so they have other diseases of the internal organs.

Another thing that it is extremely important to attend to during this period of life is the action of the excretory organs of the body; the action of these organs tends to become languid, and the most important ones to attend to are the skin and the intestinal canal. The action of the skin should be attended to by frequent washing, because if the surface of the skin is not properly cleansed its action will be impeded; and the other excretory organs—the lungs and the kidneys—will have to do the work of the skin, and these organs will be liable to become diseased, so there is no doubt whatever that a large number of the diseases of the lungs and kidneys during manhood, and during the later periods of life, is to a great extent due to insufficient action of the skin.

During this period of life such diseases as diabetes, kidney disease, gout, and chronic lung diseases, are very common, and some of the causes of them are those I have just mentioned.

We pass on to green old age and decrepit old age, and in these periods the diseases are chronic.

There are diseases that especially belong to this time of life, such as cancer, a disease for which no prevention and no remedy has yet been discovered. Gout, too, belongs more particularly to this time of life.

In old age, however, the first great thing is to avoid the cold. Cold which is so destructive to young children is destructive also to old people, and the old proverb, "A green winter a full churchyard," is like a good many other old proverbs, a total mistake. It is during cold winters that the highest death rates are observed, and this is because so many old people die from cold.

Old people cannot stand the cold, and they require to be warmly clad, and not to be exposed too much to the cold air in winter. But the reason that old people cannot stand the cold is because they cannot manufacture sufficient heat to resist it, the actions of the various organs are going on slower, respiration goes on slower, the capacity of the lungs is smaller, the elasticity of the air-sacs of the lungs is impaired, so that they do not recoil and drive out the air in the way they did when young. The respiration is enfeebled, the beats of the heart are slower, the arteries do not recoil as well upon the blood, that is, they do not force it along as well, and so there is a weakened respiration, and weakened circulation, less oxygen taken into the blood, slower circulation of the blood, less oxidisation going on in the blood, and less animal heat produced; and so old persons do not produce sufficient

animal heat to allow them to expose themselves to the cold in the way they were able to do when they were younger, and that is why so many deaths in old age are caused by the cold; the circulation of blood in the skin is impeded, and the blood is thrown upon the internal organs, some of which, being perhaps already diseased, fall readily into a state of severe disease, which ends in death through lung disease, kidney disease, and so on. The action of the skin tends to become extremely languid, and as cold cannot be borne by old people, they should stimulate the action of the skin by frequent washing with tepid water.

I may here mention that during the earlier periods of life washing with cold water is an exceedingly important thing, and it should be performed early in the morning, not merely from the point of view of cleanliness, but from the general tonic effect on the system, and people who cannot stand cold water all through the year should use the water slightly tepid. If young people do not have a proper reaction after a cold sponging in the winter, they ought not to take the chill off the water, as they are generally told to do; that makes it a warm bath, and is a mistake; but they should add just sufficient warm water to it as to make it only a little colder than themselves, so that it may have the tonic effect, and it will then have the same effect as when they take their cold bath in summer.

Perhaps the most important thing to attend to in old age, after the avoidance of exposure to the cold, is the action of the skin, and another thing is that the

food should be divided very carefully. The division of the food is an important thing during the whole of life. A great deal depends upon our masticating our food. Most of us eat our food much too fast, giving our stomachs a great deal to do which our teeth ought to do. This is a great mistake, and one of the most common causes of indigestion.

In extreme old age, of course, cold would be a very pernicious thing, but by the time an old man has got to Shakspeare's "sans teeth, sans eyes, sans taste, sans everything," he has learned wisdom, and he does not expose himself to the cold weather, and so, as a matter of fact, the cold is not the main agent of death among decrepit old people, because they do not expose themselves to it; they die because the end of their work has come, because their system has gone on working as long as it is able to work; the lungs stop working, the blood ceases to be aerated, the heart stops beating, and life is over.

There are certain precautions which should be taken while people are recovering from severe illnesses—during their convalescence.

The first sign of convalescence, or of the recovery of health after severe acute disease, such as a severe fever, is the return of hunger. During the course of the disease the patient has evinced no hunger, and you have been doing everything you could devise to induce him to take what nourishing food he was capable of digesting, although he cared nothing about it. In many diseases recovery depends upon feeding the patient. The first

sign of his getting well is hunger, and there are two things which have to be guarded against. The first is over-feeding.

The system is very weak, the stomach has been for a long time supplied with bad blood, and it is not in a condition to stand a heavy meal, and so convalescents should be fed sparingly, and with only the most digestible things. When the sign of hunger returns, they should be fed at first with milk or broths, beef-tea, and jellies, and extremely digestible things of that kind. After that they should be fed with fish, boiled fowl, and so on, until a regular mixed diet is reached. Another warning is that you should not be deceived by false signs of hunger. The true sign of the return of real hunger is the return of taste, properly so called. If a person is getting well from a severe fever, and evinces a desire to eat chalk, or sponge, or slate-pencils, or strange articles of that sort, that is a false taste, not a sign of true appetite; you ought to be more on your guard than ever about feeding him. The first sign, then, of convalescence, is the return of hunger, with a taste for proper kinds of food.

The nervous system is in a very excitable condition, because it has been long supplied with bad blood—perhaps with poisoned blood—and persons recovering from severe diseases should not be exposed to much noise by people talking to them, or else they will get headaches, noises in the ears, dizziness, and signs of that kind. Lying a very long time in bed, perhaps perspiring a good deal, the skin is rendered very sensitive to

cold, and it is extremely important that people who are in this condition should be prevented from catching cold. It is important, in all cases, but especially important during convalescence from certain diseases. One of these is scarlet fever, after which they are liable to catch cold which settles on their kidneys and produces kidney disease; this very commonly follows scarlet fever. Catching cold is a very dangerous thing after measles and whooping-cough. Children do not die from measles and whooping-cough themselves, but they often die from the lung diseases that they catch by taking cold while they are getting well.

As regards rheumatic fever, if you catch cold you are very liable to get it again, and every time you get it it is more and more likely that you will get heart disease. After rheumatic fever there is, then, a special reason for preventing people from catching cold.

There is a particular danger that arises while people are getting well from typhoid or enteric fever. In typhoid fever those glands in the small intestines, which we call "Peyer's patches," are ulcerated. Ulcers form in the small intestines during typhoid fever. Now, it frequently happens, that while people are getting well from typhoid fever, if they get up too soon and go about, or sit up in bed, one of these ulcers will break through the wall of the intestines and let the contents out into the cavity of the peritoneum, causing inflammation, extreme pain, and death; so that, in typhoid fever, you should be extremely careful, even in the mildest cases, that convalescents do not move

about too soon, because, while they are getting well from typhoid fever, these ulcers still exist; if the person remains quiet they will most likely heal up, and he will get well. I have known it occur that a person has sat up in bed, broken one of these ulcers, and fallen back dead. Exercise should be taken very gradually by persons recovering from these diseases, for very obvious reasons, because they are very weak. They should first walk about their rooms; then about in the house; and then out of doors in the freshest part of the day, when it is neither too hot nor too cold, and, of course, in fine weather.

The beds upon which sick people lie should be neither too hard nor too soft, except in the case of rheumatic fever, when it is difficult for them to be too soft. Their covering should not be too heavy, and one precaution, especially, should be taken—that is, that people suffering from rheumatic fever should not sleep in sheets, but in flannels and blankets, not in linen or cotton of any kind; and the reason is, that they perspire so copiously, that the sheets become wringing wet, and are of necessity left so, because to move persons suffering from this disease is so painful.

One of our first authors on heart disease says that he believes two-thirds of the cases of heart disease after rheumatic fever might be prevented by this simple precaution.

Ventilation of the sick room is a very important thing. Fresh air should always be admitted into these rooms, and the best way to admit it, especially if the

person is suffering from an infectious disease, is to open the windows on the staircase of the house, so as to let the air from the house into the sick room. If you open the windows in the sick room, the air from the sick room gets blown into the rest of the house; so it is necessary to have fresh air in the sick room, and, at the same time, to take precautions that that fresh air shall not pass through the sick room and carry the poison of the disease into the rest of the house.

LECTURE X.

THE AIR.

THE air we breathe, about which I am going to speak to-night, is a material substance. We feel it when it blows upon our faces, and we find it exercises pressure upon objects on the surface of the earth.

If I take a bottle of water, and invert it in a basin of water, something keeps the water up in the bottle, and that is the pressure of the external air upon the surface of the water in the basin, and that water would remain in the bottle if it were thirty feet high, because the pressure of the external air is capable of keeping up a column of water about thirty-three feet high.

Air is a mixture of gases. What do we mean by a mixture? When substances are mixed together the weight of the mixture is of course the sum of the weights of the substances mixed; nothing is lost; and the mixture has properties which are the mean of those of the substances which are mixed. For instance, if I take sugar and sand and mix them together, the weight of the mixture is the weight of the sand and the sugar together, and I get also the mean of the properties of sand and sugar, according to the proportions of sand

and sugar that I have taken ; a certain quantity will remain soluble in water, and a certain quantity not. If I make a mixture of alcohol and water, the resulting mixture will have the properties which are the mean of the properties of alcohol and water, for example, the specific gravity will be the mean of the specific gravities of alcohol and water, according to their quantities ; that is what is meant by a mixture.

Certain gases exist in the air in the condition of a mixture, so that the properties of the air are the mean properties of those gases in the proportions in which they are mixed. I insist upon this, because a mixture is a very different thing from a chemical compound, and I want you to understand that the air is not a chemical compound.

In chemical compounds the same rule holds as to weight ; the weight of a compound is the sum of the weights of the substances combined.

The difference between a mixture and a compound is that when substances are mixed we get the mean of their properties as a result, but you can never predict the properties of a compound from the properties of the substances combined, unless you have learnt previously what is going to be the result. Let us take an illustration.—Suppose I were to put out the gas and then turn the tap on, the gas would escape from the pipe and mix with the air of the room, and the resulting mixture would have properties which would be the mean of the properties of the air in the room, and the gas, according to their proportions. Now, suppose

I applied a light to that mixture, you all know that it would explode, and the result would be the production of substances perfectly different from either the air or the gas, substances of which you could not predict the production, if you did not know beforehand the result of the experiment. The substances produced when gas burns in the air are entirely different from either the gas or the air.

To show this more clearly, suppose I take a solution in water of a salt of silver, and a solution of common salt, in two different tubes ; these are two clear colourless liquids. Now, unless you knew beforehand what the result of mixing them would be, it would be impossible to predict it, for if I pour one into the other a white opaque substance, insoluble in water, is produced, which is a compound of one of the substances contained in common salt with the silver ; again, if I take a solution of corrosive sublimate, which is a salt of mercury, and a solution of iodide of potassium, two colourless liquids, and mix them, a salmon-coloured insoluble substance is produced which you could not have expected if you had not learnt what the result would be.

Nitric oxide is a colourless gas which is insoluble in water; this is capable of combining with one of the constituents of common air, and when they are put together the result is a brownish-red gas, which is soluble in water.

These experiments will show the difference between a mixture and a chemical compound.

There is another important thing to be remembered,

and that is, that when two substances are mixed no heat is given out, but when two substances are combined to form a chemical compound heat is produced.

If I take cold water and mix it with brandy it will not make hot grog, but if I take water which is quite cold and another liquid called oil of vitriol also cold, which has the property not only of mixing with the water but of combining with it, and pour them together, they combine, and heat is given out to such an extent that the vessel in which they are cannot be held in the hand because of the heat.

Another thing is that whereas you can mix substances, such as milk and water, in any proportions whatever, substances will only combine in certain definite proportions, and if when two substances are put together to combine, there is too much of one, the surplus remains uncombined, so that they only combine in certain definite proportions.

Air may be made by taking the substances which we know it to contain and merely mixing them together in the proportions in which they are contained in air, and that mere mixture has all the properties of air. Air then, is a mixture of gases. What is a gas?

The substances that are around us are commonly divided into three kinds—solids, liquids, and gases.

A solid body has a certain amount of rigidity, retains its shape and size, unless it be broken or bent. It occupies a certain space.

A liquid is a body which takes the shape of the

vessel that contains it, and it occupies a certain space in the vessel.

A gas is a body, any quantity of which, however small, will fill any space, however large, within practicable limits.

A bottle full of any gas would fill a room as well as it fills the bottle. A gas will fill a space although that space is already filled with other gases, and that is what we mean when we say that one gas is to another as a vacuum. Whatever gases there are in a space, when you put another there that fills the space all the same.

This may be easily tested by taking a bottle of gas that has an offensive smell or a gas that irritates the lungs and letting it out into a room; its presence will be easily detected by every person in the room at the time.

Not merely is this true, but gases fill a space altogether irrespectively of their weights. Whether the gas is heavy or light it fills the space all the same.

If you put a gas that is heavy into a space, that gas will not sink to the bottom, but will fill the whole space.

Let us pass on to consider the gases of which atmospheric air is composed.

Air contains three gases—two in very considerable quantities, and one in small quantity.

In 10,000 parts by volume of air, 7900 are nitrogen, 2096 oxygen, and 4 carbonic acid.

These quantities vary slightly in atmospheric air in

different places, and that slight variation is sufficient of itself to prove that air is not a chemical compound but a mixture.

Of these, oxygen, which is for our purpose the most important of the three, is a body that readily combines with other substances, and so it may be easily separated from the air.

If I take a small piece of phosphorus and light it in a vessel of air, the phosphorus will combine with the oxygen of that air, giving off a quantity of white fumes and depositing them in white flakes called phosphoric acid, a substance which is very soluble in water. That is another illustration of the fact that you cannot predict the properties of a chemical compound from the properties of the substances that compose it.

Oxygen will combine also with charcoal or carbon, and if carbon is burnt in oxygen it forms another substance which is found in the air, and is called carbonic acid gas. All the substances that we use for lighting and warming our rooms contain carbon, and in the process of burning in the air form carbonic acid gas. This gas is very heavy, so much so that in making it we can collect it in a bottle by the displacement of air from below, and we can pour it from one vessel into another. That is not contrary to what I said just now, that one gas let free in a space fills the whole space, because in these cases time is not allowed for it to do so.

Carbonic acid gas has among other properties the property of combining with quick lime, which is soluble in water, to produce carbonate of lime, which is nearly

insoluble in water ; chalk and white marble are different forms of it. If we put marble or chalk into a lime kiln the carbonic acid gas goes off, and quicklime is left.

If I take a piece of marble and pour acid over it, a disengagement of carbonic acid gas takes place which may be collected in a bottle, and if lime is introduced into the bottle with it a white deposit of carbonate of lime is produced.

If a bottle of oxygen gas and a bottle of carbonic acid gas be taken, the one a light gas and the other a heavy gas, and the bottle containing the oxygen gas be inverted over the bottle of carbonic acid gas, which is the heavier, in a few minutes we shall be able to show, by means of lime-water, that some of the heavy gas has gone up to the top and mixed with the lighter gas, thus proving what I said just now, that gases in a space will mix together irrespectively of their densities.

This is an extremely important thing to remember when considering ventilation.

If you take a candle and burn it in a bottle of oxygen it burns very much more brilliantly than in air, and is consumed faster ; but if you put a lighted candle into a jar of carbonic acid gas it is instantly extinguished, thus showing that oxygen gas and carbonic acid gas have very different properties.

We see, then, that in the air oxygen supports combustion, and that carbon, when burnt in the air, produces carbonic acid.

What does nitrogen do in the air?

Nitrogen is a substance which has purely negative

properties: it merely dilutes the oxygen gas. It has been compared to water in a glass of brandy and water, but you must remember that the other good thing in the air is oxygen; but in brandy and water I am not at all sure that the other good thing is the brandy.

Nitrogen may be made to combine indirectly with other substances, but if I put a lighted match into it, the match will be extinguished immediately, just as if put into carbonic acid gas.

Now, just as a lighted candle lives in oxygen gas, and lives in air because there is oxygen gas in the air, which combines with the carbon in the candle when it is lighted, so our life goes on in precisely the same way, and for precisely the same reasons. You know from my lecture on respiration, that when we breathe we take in air into our lungs, oxygen gas gets into the blood, and carbonic acid gas comes out into the air.

So, then, the substance that it is important for us to have in sufficient quantities is oxygen gas, and just as the candle goes out in nitrogen gas and carbonic acid gas, so animals cannot live in either of those gases, and just for the same reason. There is, however, this difference—an animal cannot live in nitrogen gas, simply because of the absence of free oxygen; but carbonic acid gas kills an animal put into it, because it is a poisonous gas, and, if in sufficient quantity, it will kill an animal although plenty of free oxygen be present.

When we breathe we take oxygen out of the air and put carbonic acid into its place, and, besides this, we add to the air organic matter and moisture. This de-

composing organic matter that we add to the air is a thing of far greater importance than either the decrease of oxygen or the increase of carbonic acid gas. In air that has been breathed, the most deleterious thing is the foul organic matter.

The second thing that is of importance is the diminution of oxygen, and the last thing that is of importance is the increase of carbonic acid gas.

One reason why I put the presence of carbonic acid as the last consideration is this, that animals will live for a long time in air that contains far more carbonic acid than the air we breathe out, while the foul organic matter, to the same extent, would be most prejudicial to them.

The carbonic acid gas in the air that we breathe out can easily be shown by taking a solution of lime water, and inserting in it a glass tube, and breathing through the tube into the lime water, when it will be found, that, while clear before blowing into it, afterwards it becomes gradually like milk ; this is caused by the action of the carbonic acid gas upon the lime, forming carbonate of lime.

What are the results of breathing air that contains these impurities?

Overcrowding in an extremely excessive form often results in death from a disease that kills very fast, a kind of putrid fever.

The most famous instance of severe overcrowding is that of the Black Hole of Calcutta, where 146 persons were placed in a space which was 18 feet each way, with

two small windows on one side. They were placed in that hole at eight o'clock in the evening, and at six o'clock the next morning 123 were found dead, and only twenty-three survived, and these all suffered from a putrid fever accompanied with eruptions of boils.

Typhus fever finds its home in overcrowded dwellings. But what is even more important is that those who are confined to small overcrowded ill-ventilated rooms suffer from *consumption*, the great plague of our climate, and so prevalent is consumption among people who live in overcrowded rooms, without a sufficient amount of air to breathe, that one author has stated his deliberate conviction that the essential cause of consumption is breathing air that has been breathed before.

How much air, then, does an individual require to breathe? Well, it can be found by direct calculation from the carbonic acid he gives out, or from the diminution of oxygen in the air that he breathes; it has also been found, from the state of the air in different places, that the air of a room is not fresh, but must be described as stuffy if the carbonic acid exceeds 6 parts in 10,000 of air (that in the outer air being four parts). You must bear in mind that it is not by reason of the small increase of carbonic acid that the air is impure, but the amount of carbonic acid is a convenient test of the total respiratory impurity.

It has been found, from these considerations, that each individual requires 3000 cubic feet of air per hour, so that if he is in a space of 1000 cubic feet, that air must be changed three times per hour.

There are other diseases besides those already mentioned, that are favoured in various degrees by breathing air that has been breathed before, but as consumption is of the greatest importance to us, I think it sufficient to insist upon the fact, that if you live in an overcrowded place and breathe air that has been breathed before, you are more liable to suffer from consumption, not to say anything of other diseases, than you would be if you lived in a purer atmosphere.

It is not difficult to find out if the air contains too much carbonic acid.

I showed you that carbonic acid gas forms a white deposit in lime water.

Now, if you mix a certain volume of air with a known quantity of lime water, shaking them up together, it is possible, by finding out how much of the lime is not deposited, to tell how much has combined with the carbonic acid, and so how much carbonic acid there was in the air. That is somewhat a complicated proceeding, but it can be modified by a very simple method, which Dr. Angus Smith calls the "household method," of examining air for carbonic acid.

Lime water can be easily made by taking a little quicklime and putting it into water in a basin. You must not put the quicklime into a bottle and then pour water upon it, else it will break the bottle, as slaking lime gives out much heat. Let it stand, and the water will dissolve a certain quantity of the lime, the excess falling to the bottom and leaving a clear solution of lime, which you can pour off and keep in a stoppered

bottle. If you put half an ounce of this clear lime water into a clean and dry 10½ ounce wide-mouthed stoppered bottle with the air in it, and then shake it up, if the lime water becomes turbid then you know the air in that room contains more than six parts of carbonic acid gas in 10,000, that is to say, that the room is not supplied with sufficient air, because you will remember I told you that the carbonic acid in the air of a room should not exceed that proportion.

LECTURE XI.

THE AIR—*Continued.*

AIR contains a small quantity of a substance we call *ammonia;* a very small quantity only, amounting to about 4 parts in 10,000,000 parts of air.

It contains also, under ordinary circumstances, a very small quantity of a substance not yet mentioned—viz., *ozone.*

The presence of ozone in the air has been doubted by a good many people; but all doubts have now been set at rest by a very admirable series of experiments. It is another form of oxygen gas, much more powerful than ordinary oxygen. It has the power of combining with most substances under certain conditions, and of combining very readily with the substances of which foul organic matters are composed, and so purifying the air.

One of the ways of preparing ozone is to take a few sticks of phosphorus, a substance which readily combines with oxygen, and to leave them for a time exposed in moist air. If you take a bottle, and put some water into it, and in the water some sticks of phosphorus projecting out of the water in the bottle, and let it stand, part of the oxygen in the air in the

bottle will be turned into ozone. This may be tested thus:—

Ozone is capable of liberating a substance called iodine, from some of its compounds, and iodine will strike a beautiful blue colour with starch; therefore, if you put a strip of paper that has been dipped in a mixture of a solution of iodide of potassium and starch-paste, into the air that has been exposed to the influence of phosphorus, if there is any ozone in the air the paper will be turned blue.

Ozone is present in very small quantities in pure air, in the air that blows from the sea, after a thunderstorm, and during a fall of snow. Its occurrence in the air is accounted for in another way. Whereas animals take oxygen out of the air, and put carbonic acid gas into it, the green parts of plants, under the influence of sunlight, do the reverse, they take the carbonic acid gas out of the air, and give back oxygen gas in exchange during the daytime.

The flowers of plants, on the contrary, and fruits while ripening, are all like animals in this respect; and so it is not right to have flowering plants in bedrooms.

It has been shown that the green parts of plants give out a certain quantity of oxygen in the form of ozone. There is always a considerable quantity of ozone present where there is much growing vegetation, and this is especially the case where there is vegetation of certain kinds.

I daresay you have heard the statement that ozone is connected with the presence or absence of epidemic

diseases, and that it is never present when cholera is prevalent. A sufficiently large number of experiments have shown, however, that it is as often present as absent during the prevalence of epidemics.

If you examine the air in a crowded hospital ward you will not find ozone there, because any that gets in with the fresh air from without is immediately used up in oxidising the foul organic matters present in the air. You cannot prepare ozone by the ordinary methods in foul air, because as fast as it is produced it is used up by the impurities; it is, in fact, nature's disinfectant.

Ozone is an exceedingly irritating substance. We could not breathe air containing much of it because it irritates the respiratory organs, and this is why it has been said to favour the prevalence of influenza and bronchitis.

There is also always a certain amount of *water* dissolved in the air, the amount of which varies at different temperatures. There may, too, be a large amount of water suspended in the air in the form of mist or fog.

Besides these matters, which are ordinarily present in the air, there is also a variable amount of *solid matters* suspended in the air. Dust, consisting of sea salt, which is blown up and carried immense distances; containing also a large quantity of particles derived from the earth, and fine sand. Ships sailing 600 or 800 miles from land sometimes have their sails covered with fine sand blown from the great African desert, and eruptions of volcanoes often charge the air with solid particles, which travel astonishing distances.

We see from this that there is a considerable amount of suspended mineral matter in the air ; there is also a variable amount of organic matter, both living and dead.

Dead organic matter, from the exhalations of animals, and from the decomposition of animal and vegetable substances. There is a very small amount, indeed, of these things in pure air, because the oxygen and the small quantity of ozone in the air decompose them, and turn them into other substances which are harmless.

There are living substances in the air, both living animals and vegetables, many exceedingly small, and only to be seen by the aid of the microscope.

These suspended matters may contain, and, no doubt, sometimes do contain, the poisons of infectious diseases, which are solid particles suspended in the air around persons infected, and from them, doubtless, these particles get into the air.

We will now consider other sources from whence carbonic acid gets into the air.

There are natural sources, besides the respiration of animals, of carbonic acid—viz., volcanoes, and mineral springs in volcanic countries, which very often emit large quantities of this gas.

It is also given out in various manufacturing processes, in the making of beer both during the fermentation of the grains to make malt, and during the subsequent fermentation, when the sugar and water is transformed into alcohol and carbonic acid; and instances are on record where persons have been suffocated by going down into the brewers' vats.

Carbonic acid gas is in itself poisonous. It is not like nitrogen, a mere harmless substance, which poisons you when you go into it because there is no free oxygen, but an animal will die in an atmosphere containing plenty of free oxygen, if it contains over 10 or 12 per cent of carbonic acid gas.

The reason that the air we breathe out is not fit to breathe in again, is not that it contains carbonic acid, but because of the presence of foul organic matter, and because it contains too little oxygen.

Suppose an animal were put into carbonic acid gas, he is put into a gas of which he has already too much in his blood, and he will die if he takes much more. Now, if the action of respiration went on for the benefit of the animal under all circumstances, and were not a purely physico-chemical action, he would not take any more carbonic acid into his blood ; but if an animal is put into a bottle full of carbonic acid gas, and the mixture that remains afterwards be examined, it is found that he has taken carbonic acid gas out of the bottle, and put oxygen into it out of his lungs, so that respiration has gone on to his detriment ; and nothing can show much clearer than this that respiration is a purely physico-chemical action, and will not necessarily go on for the benefit of an animal, but will, under unfavourable circumstances, go on to his detriment, and to his death if necessary.

A good deal of carbonic acid is given out from lime-kilns,—places where limestone or chalk is burnt to form lime. Limestone or chalk consists of lime combined

with carbonic acid, and when the lime is heated carbonic acid is given off in very considerable quantities; and cases have occurred of persons going to sleep on the ground in the immediate vicinity of a lime-kiln, because it is warm, and then being suffocated in the night by the carbonic acid gas.

The great artificial source of carbonic acid in the air is due to the substances that we use for warming and lighting. These substances contain carbon and hydrogen, and some other things in smaller quantities, and when completely burnt in the air they produce carbonic acid, water, and small quantities of other substances. If incompletely burned, some of the carbon escapes into the air in the form of soot. We all know that where gas is burned for some time in a room a considerable quantity of soot is deposited upon the ceiling and other parts of the room. Another result is the production, under certain circumstances, of a small quantity of gas which is called carbonic oxide, which consists of one atom of carbon combined with one of oxygen, and affords a remarkable illustration of the fact that when two things combine together you cannot predict the substance that will result.

Carbonic acid gas also consists of carbon and oxygen, and is a colourless gas, soluble in water, and making a precipitate in lime water.

Carbonic oxide gas is different from carbonic acid gas. When a match is placed in the latter it goes out, but when applied to a jet of carbonic oxide, that gas combines with the oxygen of the air and burns with a

beautiful blue flame, and the result of the burning is carbonic acid gas. Carbonic oxide gas is not soluble in water, nor does it produce a precipitate in lime water.

Carbonic oxide is so poisonous a gas that one part in a thousand parts of air is enough to kill an animal. It has a stronger affinity for the corpuscles of the blood than oxygen gas, so that you will see the extreme importance of all contrivances by means of which the setting free of the smallest quantity of this gas can be avoided. Here, also, is another instance of the fact I have already stated—viz., that respiration is only favourable to the life of an animal under favourable circumstances; for if an animal be placed in an atmosphere containing carbonic oxide he is killed by breathing air containing a gas which has a greater affinity for his blood than oxygen has.

We have to consider the materials used for lighting and warming, the apparatus employed, and the conditions necessary to be fulfilled in order that the substances may be completely burned, in the first place, and, in the second place, that the greatest amount of light or warmth may be got from their use, with as little detriment as possible; and we see that most detriment is caused when the substances are incompletely burned.

Now, the first among these substances that we will mention is a candle, and those candles which are the the most completely burned are always the hard candles. Soft tallow candles are never completely burned, and always throw a considerable quantity of soot into the air, and a considerable quantity of partially burned fats,

which have a disagreeable smell. The reason these soft tallow candles are not completely burned is because they melt at so low a temperature that the substance rises up into the wick faster than it can be burned. The substances of which the harder kinds of candles are made do not melt as quickly, and consequently do not rise up the wick so fast, therefore they burn slower and more completely. The result is that the injury to the air we breathe is much less. Of course these are only some of the evils, not all, as carbonic acid and water are given out into the air of a room, and you cannot have substances burned for lighting a room without this, except you have a special apparatus for carrying off the products of combustion.

With regard to oils used for lighting, the chief thing that has to be considered is the contrivance in which they are burned, so as to produce the greatest amount of light with the most perfect combustion; and the kind of lamps in which this is done are those in which the wicks are round, like the Argand burners, or in which wicks are placed parallel to one another, and in which there is a chamber of air communicating with the flame so as to ensure complete combustion.

The oils I have been speaking about are especially vegetable oils, but a large amount of mineral oil is now used for the purposes of lighting. The most important of these mineral oils is paraffin oil, made from petroleum, found in oil-wells in the United States. It consists of various liquid oils, some of which are extremely volatile, having a white solid called paraffin, and a gas

which is one of the constituents of coal-gas, dissolved in them. It is, then, a mixture of different substances, of different densities, and different evaporating points. The danger of using these substances is considerable, because when heated beyond a certain degree some of the more volatile substances contained in them rise up into the air, and form with it an explosive mixture, and a good many accidents have taken place, both in petroleum works and also where petroleum is used in lamps. And so it is important, when these lamps are used, to burn only the best kind of oil, or at any rate mineral oils that have been distilled, so that some of the more volatile substances have been driven off.

Another thing that should be carefully remembered is that some of these mineral oils have a penetrating power, and will pass through a china lamp and appear on the outside, and evaporate into the air, causing a disagreeable smell in the room.

Many of you burn paraffin in lamps, and perhaps you have noticed that invariably when you have taken hold of them you have found oil on your fingers, and then thought that the lamp had not been properly cleaned. This is not so ; the oil has come through the pores of the substance of which the lamp is made.

We will now consider Coal Gas. Gas may be prepared by the dry distillation of various substances, but is now exclusively made from coal. The coal is placed in large vessels called retorts, and heated ; various substances are given off, and something remains ; this is the valuable substance we call coke, used chiefly in

engines, when it is necessary not to have smoke, as coke burns without smoke.

The substances given off consist, in the first place, of a large quantity of tar, which is used for an immense variety of purposes in commerce, very largely for the preparation of carbolic acid, the well-known disinfectant; the aniline colours, mauve, magenta, etc., are also prepared from coal tar. Further, a considerable quantity of ammonia goes off. This is collected by washing the gas with water, which absorbs the ammonia, and this ammoniacal liquor is used for the preparation of manures, and is now the great source from which ammoniacal manures are obtained. Besides these, a mixture of gases is given off which requires to be still further purified before it can be used for burning. It has sulphuretted hydrogen in it, which has a smell like that of rotten eggs, and has to be separated from the gas, and this is done either by passing it over lime, or over oxide of iron, other compounds of sulphur being partly separated at the same time. The gas is more efficiently purified by the lime process, but the mixture of waste lime and sulphur compounds is liable to cause a serious nuisance to the neighbourhood.

The remaining mixture is the gas we burn, and it consists chiefly of a gas called light carburetted hydrogen, or marsh gas, which forms carbonic acid and water when burnt in air. It contains, also, pure hydrogen gas, which has the property of burning in air, and producing water; and heavy carburetted hydrogen gas, which burns in air to form carbonic acid and water, giving an

intense light. This last is the substance to which the lighting properties of coal gas are mainly due. Coal gas always contains carbonic oxide, sometimes as much as 11 or 12 per cent. It always contains compounds of sulphur, which, when burned in the air, produce sulphurous acid with a little sulphuric acid.

The gas we use for burning is exceedingly poisonous. It contains a sufficient percentage of carbonic oxide gas to kill any animal, and it is therefore extremely important that the gas should not be allowed to get into rooms, even in the smallest quantity. It contains one of the most poisonous substances with which we are acquainted. It is very fortunate that the gas has a very strong and unpleasant smell, as otherwise a great many people would be poisoned by it. A very foolish thing was once done. A man took out a patent for depriving the gas we burn of its smell, but the gas companies fortunately did not adopt it.

When coal gas escapes into the air, it forms a mixture which explodes very readily when a spark is applied.

What are the dangers from breathing air into which the products of the combustion of the substances we use for lighting have been allowed to escape?

It produces in persons who breathe it for a lengthened period what is called anæmia, or bloodlessness; and especially when the combustion is incomplete, and soot escapes into the air, it produces cough, lung complaints, and is particularly fatal to persons who are liable to consumption. It is, therefore, extremely important that the products of combustion should not be allowed to

escape into the air of rooms. They should be conducted away, or, at any rate, plenty of fresh air should be admitted.

I may give you an idea of the amount of damage done to the air of rooms by candles, even where perfect combustion takes place, by telling you that two sperm candles produce as much carbonic acid, and consume as much oxygen, as one man. A man in a room with two sperm candles burning requires twice the amount of fresh air that he would if he were by himself. The same is the case with a good lamp. A cubic foot of gas destroys the oxygen of about eight cubic feet of air. A poor burner will consume at least two cubic feet in an hour, and so destroy the oxygen of sixteen cubic feet of air, that is to say, will destroy as much air as four men; so that a man sitting in a room with a gas burner that only burns two cubic feet in an hour, requires at least five times as much change of air as he would if he were there by himself.

We now come to the substances used for warming purposes, and the apparatus. I will content myself with speaking about coal, and the apparatus in which it is burned. When burned in the ordinary fireplace it is burned at an immense disadvantage. About ninety per cent of the heat escapes up the chimney, but it has one advantage, and that is, that it changes the air of a room very quickly, as air must be supplied to the fire, or else the fire will go out. The only way by which air can enter to supply the fire, when a room is closely shut, is the chimney, and so air comes down

the chimney, and that is one cause of smoky chimneys.

Now, a word or two about stoves. Stoves are made of various materials, as earthenware, wrought iron, or cast iron. Quick combustion stoves very much resemble ordinary fireplaces. In slow combustion stoves coke is generally burnt, and a limited supply of air is admitted to them by a pipe from outside, so that there is no fire to be seen in the room.

They are used for warming large rooms which require a great deal more heat than is given by an ordinary fireplace. The disadvantage is that, when an iron stove gets hot, it dries the air of the room, and this dryness is only partially obviated by placing a vessel of water on the top of the stove. Another thing is that the air in which a stove is burning always contains carbonic oxide gas. That has been proved by a series of careful experiments. Another disadvantage is, that they always make the air of a room smell. You all know what is called the smell of cast iron. It is due to the partial charring of the organic matter in the air of the room, and the smell is worse if the air in the room is rather foul. So that stoves, even though they have a pipe to convey the results of combustion from a room, have great disadvantages, especially in small rooms.

The ordinary fireplace has been immensely improved in construction, and that known as the Galton stove, invented by Captain Galton, is a great improvement, though it has not been brought into sufficient use. There is an air chamber around the flue of this stove.

which communicates by a pipe with the external air, so that as the fire burns in the stove, external air comes into the chamber round the flue, is warmed, and gets into the room, partly to supply the fire, and partly to supply the room. By this contrivance as much as 35 per cent of the heat is saved, and fresh air is brought into the room, and that is of very considerable importance.

The ordinary stoves do not change the air of a room sufficiently, but there are certain kinds of stoves in which either coal or gas may be burned in which there is a contrivance for bringing fresh air already warmed into the room by a pipe running through the stove. These are called calorigen stoves.

LECTURE XII.

THE AIR—*Continued.*

THERE are a large number of trades in which solid particles and offensive gases are given out into the air.

For instance, in the air of mines there is a large quantity of finely divided solid particles which get into the lungs of the miners and set up irritation there, often resulting in consumption; and consequently among men who work in mines there is a large death-rate from that disease, because consumption, in manhood especially, attacks the lungs.

It has been ascertained that the death-rate from consumption among miners who work in mines in which the air is changed rapidly, is very much less than among miners who work in mines that are badly ventilated.

In potteries, china works, pearl button manufactories, glass polishing, and cement works, there is a large amount of foreign mineral matter in the air, and the workpeople in them suffer from a high death-rate; this high rate of mortality might be lessened if the solid particles were prevented from getting into the lungs of the workmen, and if these workmen could be persuaded to wear some kind of mask or respirator, by means of which they could breathe and, while breathing, filter the air and separate the solid particles from it, the death-

rate from lung diseases and consumption would be considerably diminished. But there is much difficulty in inducing workmen to adopt any such measures; they cannot see that they are for their benefit.

Then, again, workers in iron, and especially in steel, are exposed to the influence of fine particles getting into the air. These might easily be separated by wearing a kind of magnetic mask which has been devised, through which they could breathe, but which would collect the minute particles and prevent them getting into the lungs.

The workers in zinc and copper, especially in places where these metals are smelted, are subject to special forms of poisoning; but much of the lead poisoning or painters' colic, which is a disease causing severe pains in the intestines and paralysis, could be prevented by greater cleanliness. These diseases are, in many cases, not caused by breathing air impregnated with the solid particles given off in the process of working, but are the result of the want of cleanliness of the workmen's hands, particles of white lead, etc., thus getting mixed with their food, so that greater cleanliness, in some cases, would do almost all that is required. Workers in mercury, makers of mirrors and looking-glasses, also suffer from a similar kind of paralysis.

There is a beautiful paint containing arsenic and copper, which is very commonly used in colouring wall papers green. It is called Scheele's green. In damp weather persons who live in rooms decorated with such papers are subject to various symptoms of arsenical

poisoning, the most obvious of which is a severe irritation of the lining membrane of the nose and eyes. Moreover, green is not the only colour in use that is produced by arsenical compounds.

Besides the masks and respirators which I have mentioned, a great deal may be accomplished in almost all cases by frequent change of air and good ventilation.

There are also a great many manufacturing processes in the working of which organic matters escape into the air in the form of dust. For instance, in the spinning of cotton, of wool, and of silk, there is an enormous amount of the fine fibres of these materials given off in the form of dust, and those who work in spinning-mills are subject to lung diseases.

It is difficult to procure good and efficient ventilation in these rooms, because a considerable amount of warmth is necessary, and so, as a matter of fact, these places are kept as close as possible.

Offensive organic matters are given off into the atmosphere in many instances, as in gut spinning, bone boiling, tallow melting, etc. It is difficult to show directly that these matters are injurious to health, but, at any rate, they are extremely offensive, and those places in which such processes are conducted could be made much less disagreeable by carrying the fumes given out during the boiling through the furnace, by means of a flue rising from the boiler and connected with the furnace; a practice now very commonly adopted.

Matchmaking, until a comparatively recent date, was attended by a frightful disease which attacked the

jaw-bones. This was caused by the particular form of phosphorus which was then used, the form I have shown you several times—vitreous phosphorus. It is very volatile, highly poisonous, rapidly oxidises in air, readily catches fire, and gives off irritating vapours; but happily a form of phosphorus was almost accidentally discovered which is comparatively harmless. I told you that there are two forms of oxygen; in the same manner certain other bodies are found in various forms. For instance, we find carbon as soot, or as plumbago (black lead), graphite, or as the diamond, and it was discovered that there was also another form of phosphorus which goes by the name of red phosphorus. It is not as volatile or poisonous as the other; it does not combine anything like as readily with oxygen in the air. The introduction of this in the manufacture of matches abolished, practically speaking, the disease to which the makers of matches were formerly subject.

In the manufacture of india-rubber articles a curious substance is used which is called bisulphide of carbon, a combination of carbon and sulphur. It is a beautiful clear yellow liquid of an extremely offensive odour, very volatile, and has the property of dissolving india-rubber.

For a long time india-rubber was comparatively little used, because it was not known how to dissolve it; but when it was discovered that bisulphide of carbon was capable of dissolving it, and then could be evaporated, it was found that articles could be made of any shape or form.

People who work with this substance suffer from the vapour it emits, which is very heavy, and so keeps low down in the room. A great number of india-rubber articles are made by poor people in their own homes, not in manufactories, and when the vapour given off in the process of working this material is breathed it causes various symptoms, as headache, nausea, and convulsions, and in the end paralysis. The way to prevent this is to see that the rooms are well ventilated, and especially that the air of the lower part of the apartment is frequently changed. Fortunately the vapour is a very irritating substance, and so its presence is easily detected.

In the manufactories of chloride of lime (bleaching powder), and in places where it is used for bleaching wool and other materials, chlorine gas is given off into the air, and irritates the respiratory passages when breathed, from which we can see that these places should be very thoroughly supplied with fresh air.

A compound of chlorine called hydrochloric acid is given out in large quantities during the preparation of carbonate of soda. Soda is prepared in enormous quantities from sea salt, and the vapour evolved during its manufacture is an extremely irritating gas, which used to be allowed to escape into the air from tall chimneys, but is now, however, absorbed by passing the fumes through condensing towers in which there is coke washed with a stream of water.

During the preparation of sulphuric acid, sulphurous acid gas is set free, but the manufacturer finds it is a

great disadvantage to him to allow this to escape, and so he takes care that as little as possible shall escape.

Now, wherever there is foul organic matter decomposing, a gas is emitted in greater or less quantities, called sulphuretted hydrogen, which has an exceedingly offensive smell like that of rotten eggs. This gas is given off in sewers and cesspools that are badly ventilated. When in sufficient quantity it causes suffocation, which is so sudden that it goes in France by the name of *le plomb*, because the suffocated person falls down like a lump of lead. We can gather from this very clearly the great necessity of well ventilating places where this gas is at all likely to collect. In addition to this the fumes of ammonia are evolved. This is also an exceedingly irritating substance, and mostly affects the mucous membrane lining the eye-sockets, so that persons who work in an atmosphere impregnated with it suffer from inflammation of that mucous membrane. All this shows the great importance of not allowing accumulations of foul organic matters to be formed.

Let us pass on to consider the methods by which the air in our rooms can be frequently changed.

I have told you in a previous lecture that it is necessary that an individual should have 3000 cubic feet of air per hour to breathe. It has been shown by theoretical calculation from the changes produced by respiration in the air, that 2000 cubic feet per hour per head are required, but it is found on analysing the air in rooms in which there are large numbers of people, that this quantity is not sufficient to prevent the air

from being stuffy, and 3000 are necessary. Sick rooms and hospital wards require more than ordinary places, and this quantity makes no allowance whatever for the impurity that gets into the air from lights. How, then, is this quantity of air to be obtained? It is perfectly clear that we cannot have apartments large enough to hold the required quantity, for suppose we remain seven hours in a bedroom with no supply of air from the outside, we should require a bedroom large enough to contain 21,000 cubic feet of air for each person in it. It is clear, then, that the air of the room must be replaced a considerable number of times. How is this to be accomplished? Among the possible sources of the movement of air we have the property of the diffusion of gases. If there is a space containing gases of one kind in communication with a space containing gases of another kind, by the law of the diffusion of gases they will mix throughout; but foul organic matters do not obey this law.

Then we have the action of the winds, and they are an exceedingly powerful means of ventilation, but they are irregular. A wind that blows so slowly that it is imperceptible will change the air in a large room in a very short space of time. Then there are movements in the air that are caused by variations in its density or weight, and these variations in weight are generally produced by differences of temperature. When the air is hot it is light, and when cold it is heavy, and the changes produced by this means are of great importance with regard to ventilation.

In this climate we cannot bear the air of a room to be changed more than three or four times in an hour. If changed more frequently there is a draught, and we can therefore see that since we must have 3000 cubic feet per hour, we should have from 750 to 1000 cubic feet of space each.

How, then, is the change to be accomplished and to be effected without draught? In the first place how can the wind be utilised? This can be always done in a building which has windows on both sides; all we have to do is to open the window nearest to the direction from which the wind comes, and also the one diagonally opposite, at the top, when sufficient currents of air will be produced to change the air in the room without any draught. But, of course, in a quite still atmosphere this plan is of no avail. Wind has been used for ventilating the holds of ships, and in that case a cowl is so constructed that it always faces the wind, and so fresh air is conducted down into the hold by pipes, and the foul air is driven out through various passages. This method is known as Sylvester's mode. It was put into practice by a Dr. Neil Arnott to ventilate a large school. He had a cowl which always faced the wind, and the air was carried by a pipe down into the basement, where it was warmed; then it rose upwards through apertures into the apartments of the school, and from thence was conducted by another pipe to the outside, which pipe was surmounted with another cowl, so constructed as to always face away from the direction of the wind, and in this way he utilised the wind which-

ever way it blew. Wind acts directly as a ventilating agent by displacing air that is before it, and indirectly by aspiration. When air is blown forcibly across a tube it causes a diminution of pressure in the air in the tube; and so air blowing across the top of a chimney causes an up-draught in the chimney.

These are the chief ways in which the wind has been utilised, but the objection is its irregularity. Sometimes it is too strong, at others too weak.

How are differences in the weight of the air to be utilised? The first thing we have to consider is the condition of the air in an apartment. The air that we breathe out, and the air given out by lights are hot, and consequently are light, and rise to the top; and for that reason the air in the upper part of an apartment is always more impure than in any other part. If you construct a closed chamber, and put lights into it, the top lights will go out first.

From this we see that the impure air we want to get rid of is chiefly at the top of the apartment, and the pure air low down.

Another thing to be considered is, that the air outside is colder than inside, and therefore heavier, and so whenever we make an opening from the outside to the inside the cold air will pour in. Now, those who first began to think about these matters, considered that as the foul air is warm, and at the top of the room, if they made an opening at the top the impure air would go out; but instead of that fresh air comes in, and you see why, because outside there is heavy air, and inside there

is light air, and the exit for the air is up the chimney, so that the apartment is in precisely the same position as a box when you put it under water. There is another way in which air will come into a room, besides by openings specially constructed. It will come in through all openings, through the chinks of the windows, through the keyholes. Air will also come into a room from the outside through the walls. A very considerable quantity of air penetrates into rooms through the walls, when the outside air is much colder than the inside. I may tell you that Professor Pettenkofer has shown that you can blow a candle out through a brick if you only concentrate the breath on one point; and so a large quantity of air is changed in rooms by the air passing through the walls when there is no contrivance to prevent it, and it is a fact that many rooms, when shut up in winter, are much better ventilated than in the summer, when the doors and windows are open, because at particular periods there is scarcely any movement of the air in summer, whereas in winter the cold air outside, and the warm air inside, form a current of air, and a large quantity passes through the walls. It remains, then, for us to consider how air is to be got into rooms so as not to produce draught, and how the air that has been used is to be drawn out. Cold air must be let in above people's heads, or it will produce a draught, and the practice has arisen of letting it in high up in a room. Now, if you make an opening through the wall of the room into the outer air very high up, the outer air will come in, cold and heavy,

into the air which is lightest at the top of the room, and so it will fall down, just as cold water would, on to people's heads, and that clearly will not do. That is to say, then, that you cannot let cold air in low down, as it will get to your feet; and you cannot let it in high up, as it will fall on your head. What, then, is to be done? You must let the air in so that it shall have a direction upwards, so that it shall come in like a fountain. There are several ways of doing that. Suppose you make an opening over the door through the wall into the outer air, and you put in front of that a piece of board slanting forward, air coming in strikes against that board, and is deflected upwards, so that it ascends as it comes in, and if you provide that board with what are called a pair of cheeks to prevent the air tumbling over at the sides, you have a very cheap way of letting air into the room. One precaution you should take, and that is, that you should not do that too high up in the room; you should put it low down, only just sufficiently above people's heads. Now, many people do not like to go into a room where they see anything of the kind, and there are people, too, who directly anything of that kind catches their eye, think they feel a draught, but I can assure you that in a room provided with a contrivance of that kind there is no draught, it is pure fancy, and I would advise the plan as one worthy of general adoption; and I would suggest that you should conceal the piece of wood by hanging a picture in front, and then your nervous friends will not be annoyed. This contrivance has been brought under

more control by an apparatus known as the Sherringham valve, which was invented some time ago, and answers its purpose very well indeed. It is a heavy iron valve, having a box which fits into a hole made in the wall; on the other side of this box is frequently placed a piece of perforated zinc, but an iron grating to keep birds out is all that is necessary, and is preferable. It has a heavy valve which is open when the box is in position, and this is a very good point about it. It can be shut by pulling a string if required, or it can be kept at any angle, because there is a weight which just balances it, and it has two cheeks to prevent the air falling over sideways. If this valve be used it should not be placed too high up in the room. A good many people are dissatisfied with it because they say the cold air falls down into the room, but the reason of that is that the apparatus has been placed too near to the ceiling, so that the air, after entering, immediately strikes the ceiling, and rebounds downwards into the room; if placed a little above people's heads it does not cause a draught.

I have to mention next a very simple means by which air can be introduced into a room by means of the window, so as to go upwards, even in the coldest weather without anybody experiencing a draught. A piece of wood, about three inches high, which runs the whole width of the window, is placed underneath the lower sash, which is shut down upon it; this of course prevents the top and bottom sashes fitting in the centre of the window, and an opening is left, so that air

comes in and goes upwards. It has a small disadvantage, and that is, that there is no provision for the exclusion of blacks, but that has been to a certain extent rectified by one of Mr. Tobin's plans. He does not put a block underneath the lower sash ; he cuts little pieces out of the bottom piece of wood of the top sash, and the air comes in and goes straight up, and no one can see that the holes are there. You can even hold a candle in front of the window, and no effect whatever is shown upon the flame. Into these little holes he introduces a small box, and fills it with cotton wool, keeping the wool in its place by little threads passing from side to side. That wool filters the air so that no blacks can come in. You can also have some small lids fastened on to the top part of the bottom sash to turn over and cover the holes whenever you choose, so as to prevent air coming in at all. If cotton wool is used it must be changed pretty frequently, for it is astonishing how soon it gets dirty.

Louvre ventilators are made of slips of wood, glass, etc., very much like Venetian blinds—which latter make good ventilators if you open the top of the window, and turn the blind so that the laths slope upwards.

Windows have been constructed so that when the top sash is lowered it pulls down a contrivance made of louvres, but this is rather a complicated arrangement. Louvre ventilators, made of glass, are largely used, and can be put into a window instead of one of the panes. You can open or shut them, and put them at any angle

you please. The disadvantage that they have is that the metal framework is liable to rust so that they will not work, but with care they do very well.

Windows which slope when they open are used sometimes, and they afford a very good means of letting a large volume of air into assembly rooms, etc., which are liable to be overcrowded.

In some cases, especially where French casement windows are used, Cooper's circular disc ventilator is fixed. It is entirely made of glass—a circular disc with five holes in it, corresponding with five holes in the pane. The disc can be turned so that the holes in it are or are not opposite to those in the window-pane, so that air can be admitted or not at pleasure. One advantage of this ventilator is that it has no metal framework, and so cannot get rusty.

In conclusion, I will mention the vertical shaft plan, which was re-introduced a short time ago into this country by Mr. Tobin. Its action depends upon the principle described just now; wherever you make an opening into the outer air, air will come in, by reason of the greater pressure outside, and if you admit air into a room through a vertical shaft, the air will rise up through the shaft and come into the room like a fountain, but no draught will be felt. One advantage of this plan is that you can filter the air in various ways, by passing it through cotton-wool, or you can pass the air over the surface of water placed in the tube leading to the vertical shaft, deflecting the air on to the surface of the water by causing it to strike against sloping pieces of

metal. In that way the suspended particles in the air are driven, as it were, on to the surface of the water, and the air passes on into the vertical tube which rises up into the room. That is a very admirable contrivance, though not so simple as some of the methods I have before described. I should add that it is patented.

Now let us consider the ways in which foul air gets out of rooms. In the first place, a very large quantity of air passes out of all rooms by the chimney, whether there is a fire or not, provided that fresh air can come into the room somewhere else. Whenever the air outside is colder than the air inside, the air will go out through the chimney; that is partly due to the diminution of pressure, which causes an up-draught in the chimney whenever air is moving over it, which is nearly always the case. It has been thought by many that it would be advisable to have some means by which the air at the top of an apartment, which is always warmest, could be drawn off; and one of the earliest contrivances to effect this was Neil Arnott's valve, which is a valve placed in a box, opening into the chimney; it is a very light metal valve, which can only open towards the chimney, so that whenever the pressure of the air in the room is greater than that of the air in the chimney, it opens and allows air to escape from the room into the chimney, and when the contrary is the case it shuts, and so prevents the air in the chimney from coming into the room, and when it is not required it can be fastened by means of a string attached to it. The disadvantages of that valve are, that after

a time it gets out of order, and does not close so easily, and so a certain amount of air and blacks from the chimney get into the room ; it also makes a clicking noise, which is unpleasant, especially in a bedroom. You can sleep if there is a clock in the room, because the ticking is regular, and you get accustomed to it, but it is extremely unpleasant and disturbing to have an irregular ticking or clicking. That valve was improved upon by Boyle, who, instead of employing a metal flap to be blown by the air towards the chimney, used a series of little pieces of talc, which acted in precisely the same way as Arnott's valve ; but if you blow against these little flaps from behind with a sudden strong gust, the air catches underneath their edges, and opens instead of shutting them. A better plan than either of these is to have a separate shaft, side by side with the chimney, so that the air is warmed by contact with the flue, and an up-current is promoted in the shaft which communicates with each room, and so air is extracted without any possibility of blacks getting into the house.

The next is known as M'Kinnell's ventilator. In this there are two tubes, one inside the other. They are let into the ceiling of a room, and made to end outside, at different heights; the heated air escapes through the inner tube, and the cold air from the outside comes down between the two tubes, and is deflected horizontally into the room by a metal rim placed round the end of the inner tube, and parallel to the ceiling. The action of that ventilator is very much increased if a gas

jet be placed below the inner tube. It is upon this principle that railway lamps are made.

Another ventilator which is constructed upon the plan of M'Kinnell's is one in which the outer tube is provided at its upper part with vanes, which catch the wind, and so the air is deflected down into the space between the two tubes and into the room through perforations which are just below the ceiling.

A modification of these contrivances may be used in rooms where there is another room above, so that you cannot have tubes going up into the outer air; it consists of a like arrangement of tubes, and they end between the ceiling and floor of the room above, between the joists upon which the floor rests; and on each side of the house there are air bricks let in so that the air comes in at one side, and blows out at the other. These are known as Tossell's ventilators.

In artificial ventilation, by means of which air is forced into places, or drawn out, by machinery, the chief agents that are used are large fans, consisting of metal vanes placed round an axle, like the spokes of a wheel—either large propelling fans, by which air is driven into the places and allowed to get out as it can, or by channels leading to flues; or extracting fans, which draw air out of the places, and allow it to come in from the outside through channels provided for it. In this way many of our mines are ventilated.

Drawing air out by means of large furnaces is also generally considered to be a part of artificial ventilation, but the principles are precisely the same

as those described with reference to the ventilation of apartments.

In sunlight ventilators there is a large extraction shaft around the tube which carries away the products of combustion of the gas, and the ventilating power of this shaft is sometimes increased by connecting pipes with it conveying the products of combustion from the gas-burners in various parts of the building.

In buildings warmed by hot-water pipes the air admitted may be warmed by allowing it to pass over heated pipes, and the shaft through which the pipes pass from the boiler in the basement to the upper parts of the house may be used for the purpose of extracting air.

LECTURE XIII.

FOODS AND DRINKS.

WE are continually, as you know, getting rid of certain substances from our bodies. We get rid, in the first place, by means of all our excretory organs, of a considerable quantity of water; we get rid of that from the lungs, skin, and kidneys. We get rid of mineral salts especially in the secretion of the kidneys; of carbonic acid especially by the lungs, but also by the kidneys and skin; and of matters containing nitrogen—viz., a substance called urea, and another called uric acid—almost entirely by means of the kidneys.

It is necessary that these losses should be replaced. Besides this we are continually exerting force in various ways, and it is necessary that, in some way or another, this force should be generated.

So we see the necessity of taking certain substances into our bodies, and we have already seen how one substance, viz., oxygen, is obtained.

We will now go on to consider the other substances that are taken into our bodies. These we get from the mineral world, the vegetable world, and the animal world, but we may say that we get them all indirectly from the mineral world, because vegetables build up their structures from the substances they get from the

mineral world, and we eat vegetables, or we eat the flesh of animals that have themselves fed upon the vegetable world.

Now, since the substances that our bodies are made of are exceedingly various in their composition, and since all parts of our bodies waste during use, and require to be repaired, it is quite clear that the food we eat must be of a mixed kind. It must contain a large number of substances ; no one substance at any rate, and not even two or three, would be sufficient for food for us, or for any animal.

So, then, we eat foods that are made up of a great variety of substances. The substances of which these foods are made up may be classified, and the first group includes substances belonging to the mineral world, viz., water and mineral salts. Since two-thirds of the weight of the body consists of water, and as we get rid of water by all our excretory organs, it is quite clear that we must take a considerable quantity of water in our foods ; but this will be more fully considered in a separate lecture. We take, also, mineral salts in our food, directly and indirectly ; we take them directly in the form of condiments, and the most important of the mineral salts for us to take is common salt, or chloride of sodium. This salt is found in all the tissues, in the blood, and in all the fluids of the body. No doubt, one action of it is to promote the flow of saliva in the mouth, but that is not the only action ; it is a food that is necessary to our existence, and to the existence of animals generally. Animals, in countries where

common salt is scarce, go for hundreds of miles to have a lick at the salt rocks.

We get common salt, in some countries, from the sea-water, which contains a considerable quantity of it. In Norway it is got by freezing sea-water. It is obtained in some countries by evaporating sea-water. It is, however, got in much larger quantities from rocks containing salt. In this country there are enormous salt-works in several counties, notably in Cheshire and Worcestershire, where it is obtained either by digging it out, or more generally by pumping out the salt water contained in the fissures of the rocks. This brine is then evaporated, and the salt remains.

Other salts may be used as condiments instead of common salt, but they cannot replace it as a food.

Then we require salts of lime, and especially phosphate of lime, because almost all our tissues contain salts of lime and phosphate of lime. All animals contain a certain quantity of phosphoric acid.

We get phosphates indirectly, and we get them chiefly in the grains that we eat, especially in the grains of cereals—wheat, barley, oats, maize, rice, and so on—and they get it in turn from water. The rain-water which falls on the soil dissolves phosphate of lime, and these plants collect it and enclose it in their grains. We get phosphates, too, to a certain extent in the meat we eat. We require a great number of other salts, but only one or two others that I wish to mention—salts of potash, from green vegetables, and salts of iron. Iron is a necessity for the existence of animals, because it is

one of the constituents of the red corpuscles of the blood, and we obtain it especially in the red meat that we eat, also to a certain extent in most of the other foods. These, water and mineral salts, go by the name of inorganic food substances.

We have, besides, a class of food substances that we call organic food substances, because we get them from the organic world.

Now, some of these substances are composed of carbon, hydrogen, and oxygen; they contain no nitrogen, and so they are called non-nitrogenous foods. They are of two kinds—one class includes fats and oils, and the other class includes such foods as starches, sugars, and gums. Fats and oils contain a very large quantity of carbon and hydrogen, but very little oxygen; but starches, sugars, and gums contain a large quantity of oxygen, on an average amounting to half their weight; and besides these there is a small division which consists of certain organic acids that we get from the green vegetables—citric acid, tartaric acid, etc.; and lastly, alcohol must be mentioned under this head.

Organic foods that contain nitrogen are called nitrogenous foods; they contain carbon, hydrogen, oxygen, nitrogen, and very often sulphur or phosphorus. Now these nitrogenous food substances are also divided into two large classes, and one smaller and less important class. The first class, which is the most important of all, includes substances like albumen and fibrine, substances that contain a considerable proportion of nitrogen, and that are called albuminous bodies or protein

compounds; and the second class includes one important substance—viz., gelatine, and a few less important ones. There is also a smaller class containing nitrogen, which includes the essential principles of tea, coffee, cocoa, etc.

Among substances that do not contain nitrogen there are, then, two important classes, the fats and oils, and the starches, sugars, and gums. We shall see what becomes of these when they are taken in our foods.

The fats that are taken in our foods are not altered in the mouth, they are not altered in the stomach, but in the small intestine; when mixed with the pancreatic juice and bile, they form what we call an emulsion. I can best illustrate what is meant by an emulsion by mentioning milk, which contains very various substances: one is fat, which is in the state of an emulsion, being divided into very small particles.

Fat, then, is reduced by the action of the pancreatic juice into the state of an emulsion; the fine particles of fat then pass through the walls of the villi of the small intestine into the lacteal vessels, which begin in the villi, and so get into the blood unchanged; then part of the fat combines with the oxygen in the blood, and because there is a large quantity of hydrogen and only a small quantity of oxygen in the fat a very large amount of combination can take place, for almost all the carbon and hydrogen can combine with free oxygen in the blood, so that a large amount of oxidisation occurs, and a considerable quantity of heat is produced. Fats are among the most important foods that we have for pro-

ducing heat; they partly do this, and partly are deposited in the various tissues.

Another important function that fats perform is that of aiding the digestion of other substances. An animal cannot live upon a diet that contains no fat, because he cannot properly digest or absorb the other substances contained in his food.

What becomes of the sugars, starches, and gums? They are converted in the mouth by the saliva into a form of sugar which goes by the name of grape sugar. When the food gets down into the stomach no further change occurs, but in the small intestine, if all these substances have not been changed in the mouth, the pancreatic juice changes the remainder into sugar, which is absorbed into the blood-vessels of the villi, and passes through the portal vein into the liver. It has been shown that the blood in the portal vein contains sugar, but the blood in the vein that leaves the liver does not contain sugar, and the blood generally in the body contains no sugar, or only a very small quantity: when, either from disease or other cause, the blood does contain sugar, especially if in large quantity, it is got rid of by the kidneys as sugar. What, then, becomes of the sugar that goes into the liver? It has been found by a large series of experiments that the liver is capable of preparing, out of the substances that come to it in the blood, a substance that goes by the name of liver starch, some of which it stores up, and the liver in consequence always increases in weight after the consumption of a diet containing much starch. This starch is a substance capable

of very readily being turned back again into sugar, and that is why it goes also by the name of glycogen, which means sweet producer. But it is found that ordinarily there is very little or no sugar in the blood that leaves the liver; what, then, becomes of the liver starch stored up in it? The liver has at least one other property—that of manufacturing fat; but the precise way in which this is done is not understood: it is probably from the liver starch, though other substances may have something to do with the process; so that the liver may be regarded as an important apparatus for manufacturing fat and turning it into the blood, and so we see why people who take large quantities of food containing starch frequently become stout, and how it is that animals, especially poultry, are fattened upon foods containing a large percentage of starch and very little fat. In this way these food substances, starches and sugars, are turned first into grape sugar, and then by the liver they are changed into fat, which is disposed of in the ways already described. We can perceive, then, that non-nitrogenous foods have especially the important function of combining with oxygen in the blood and producing animal heat, and for this reason they have been called calorific foods.

No mixture of non-nitrogenous substances is capable of keeping up the life of an animal, because loss of nitrogenous matter is occurring continually, and so it is necessary that foods containing nitrogen must be taken. When any tissue is used it wastes, and that waste must be replaced.

Then with regard to nitrogenous foods: the first class of these includes albumen, which we find pure in the white of an egg, also in meat; fibrin and syntonin, which we also find in flesh: it also includes casein, found in milk; legumen, found in beans and peas; and several others. These substances are known by the name of protein compounds. They are not attacked by the saliva in the mouth, but they are attacked by the gastric juice in the stomach, and are converted into substances that go by the name of peptones, and are absorbed from the chyle into the blood through the walls of the capillaries of the villi, and also into the lacteal vessels of the villi.

These substances go especially to form tissue, and so the nitrogenous substances have been called tissue-forming foods. But they do not solely contribute to that purpose, some part being oxidised in the blood, with the waste nitrogenous substances from the tissues, which are also oxidised in the blood, forming the nitrogenous waste that is got rid of by the kidneys.

No dietary, therefore, is complete without one or more of these nitrogenous foods. Some time ago it was thought that the force we exerted was due to the oxidation of the nitrogenous substances of which our muscle is composed, but it has been shown by experiments made by different observers that this is not the case, but that the force we exert is produced by the oxidation of the non-nitrogenous substances in our foods, of the substances containing carbon, hydrogen, and oxygen, but no nitrogen, and that the greatest exertion can be supported

for a time upon non-nitrogenous foods. It is clear that if force were produced by the oxidation of the nitrogenous substances, the amount of nitrogenous waste that we excrete from the kidneys during exercise ought to be greater, in proportion to the exertion. This is not found to be the case; on the contrary, it is the amount of carbonic acid that we excrete, and the amount of water that passes off, that are in proportion to the amount of work done. It is therefore certain that the main object of the non-nitrogenous foods is to produce heat by being burnt in the blood, and thus keep us at a proper temperature, and supply force for the work we do; and the chief use of the nitrogenous foods is to repair the waste of the nitrogenous tissues, and only to aid in a secondary way the production of animal heat; in fact, the muscular tissue of the body is really the apparatus by which force is exerted, and that force is not due to the heat produced by the oxidation of the muscular tissue.

These, then, are the chief substances contained in foods.

The diet of an adult doing an average amount of work should consist of a mixture of the food substances I have just described, in the following proportions:—Substances containing nitrogen, 4½ ozs.; fats, 3 ozs.; carbo-hydrates (starches, gums, sugars), 14¼ ozs.; salts, 1 oz.—total, 22¾ ozs. of dry substances (containing no water). This, in the form of moist food, is equivalent to about 40 ozs. of food; and, besides this, he should have from 70 to 80 ozs. of water.

These are the quantities necessary when an ordinary amount of exertion has to be undergone; of course, if greater exertion is required, much larger quantities of these substances must be taken, and especially of the carbo-hydrates, and also larger quantities of the nitrogenous substances, though not in proportion to the amount of work performed.

It was found during the construction of the North of France Railway, that the English workmen did much more work than the Frenchmen; and they tried to find the cause, and discovered that the English took a considerably larger quantity of meat with their food; the Frenchmen were then put on the same diet, the result being that they were able to equal their English comrades in the amount of work performed; so it is quite clear that hard work cannot be done without an increase of nitrogenous as well as of non-nitrogenous foods; and this is because the tissues are being used faster, and require to be repaired.

If less than this amount of food be taken, the same amount of work cannot be performed for any length of time. If the amount be considerably less, say 16 ozs. of dry substances, then starvation begins, the tissues of the body begin to waste rapidly, faster than they can be replaced. If more than this quantity be taken with an insufficient amount of exercise the result is what is called plethora, in one form or another. If a great excess of non-nitrogenous food be taken, and little exercise, the result is the production of fat. On the other hand, if too large an amount of nitrogenous food

be consumed, with but little exertion, then the consequence is gout or some kindred disease.

I must now speak to you more particularly about gelatine. This has for a great number of years been considered a very important food. It is certainly an extremely digestible substance. Jellies are given to invalids because they can digest them. But a series of experiments was made some time ago in France which threw great doubt upon the nutritive power of gelatine, and which made people begin to think that jellies were of no use at all as food. This, however, is against the experience of ages. It was found, for instance, that dogs would not live upon gelatine, and that they did as well without it as with it. It is not likely that dogs would live upon gelatine ; no animal will live upon any one thing. A dog will live upon bones, but not upon gelatine prepared from the bones. More recent experiments have shown that gelatine is an important food in this way, that it can take the place of part of the nitrogenous substances which are being oxidised in the blood. It seems likely that gelatine cannot take part in forming tissue in the body, but it is certain that it is oxidised in the blood. So in the case of an invalid suffering from an acute disease, who cannot digest strong nitrogenous food, waste is going on from his body, and it must come from his tissues ; he cannot digest ordinary meals, but he can digest gelatine, and this is oxidised in his blood, and prevents the tissues from being wasted so fast. Although it does not go to form tissues it is certainly oxidised in the blood, and so is

an important food in cases where other nitrogenous foods cannot be digested.

We will now pass to the consideration of the foods we do actually eat and drink.

In the first place, almost all these foods are mixtures of several of the substances I have been describing as essential food substances, but there is only one of these things that contains all the substances that are necessary for nourishing an animal, in proper proportions, and that one is milk, which is the natural nutriment of all young animals of the order mammalia for a certain time. It contains about 87½ per cent of water, and about 12½ per cent of solid matters. The milk from town-fed cows is richer than country milk, because the cows are mere machines for making milk; they do not go out into the fields and spend their energies, and therefore the town milk contains about 14½ per cent of solid matters instead of 12½ per cent.

What are the solid matters in the milk? In the first place it contains salts, which are in the proportion in which they are wanted, salts of lime, especially phosphate of lime, salts of soda, potash, magnesia, and others I need not mention, and it contains also iron. It contains fats which are in the form of an emulsion, and when the milk is allowed to stand these fats partly rise to the top in the form of cream. One of these fats contains phosphorus, and such a fat is found in the nervous tissues of all animals. It contains sugar—viz., lactose or sugar of milk, and it contains nitrogenous substances, the chief of which goes by the name of casein;

it forms the curd of milk, and is the most important ingredient in cheese.

The milks of various animals have slight variations in their composition.

I will now describe to you a simple way by means of which you can tell for yourselves pretty accurately whether a specimen of milk is genuine or not; of course an accurate analysis of milk can only be made by chemical processes, performed by an experienced person in a chemical laboratory, but it can be examined sufficiently to arrive at a pretty accurate conclusion in this way:—Milk contains solid substances in solution; it is heavier than water, and has a density of about 1030, water being 1000, and an instrument has been made, called the lactometer, which shows the density of the milk in which it is placed. It consists of a hollow glass bulb, having some mercury at the bottom of it, and a stem which is graduated in degrees from 1035 downwards to 1000. Immediately this instrument is plunged into milk, it is clear that it will sink, and that the depth to which it will be submerged will be regulated by the greater or less density of the milk in which it is placed.

This is not sufficient of itself, because milk that contains a very large proportion of cream is lighter than milk that contains less, and so sometimes in very rich milk this instrument will stand very low down, and, on the other hand, substances could be added to increase its density. However, for all practical purposes it may be fairly assumed that milk is only tampered with by

adding water, or by removing cream. A second test is easily made by means of an instrument called the creamometer: it consists of a tube divided into 100 parts, and it should be filled up to the top mark with milk, which should be allowed to stand for at least 12 hours, for the cream to rise; the amount of cream varies a great deal, but it should not be less than ten per cent by volume. If a sample of milk gives less, and at the same time the lactometer sinks low in it, then you may be almost certain that water has been added; if, on the other hand, with too little cream the lactometer stands at 1030 or higher, the milk has not been watered, but has been skimmed.

The food that most nearly approaches milk in its capabilities of nourishing an animal is an egg of a bird. You will at once understand this, as a young bird is formed of it; the egg must contain all the substances that are necessary to make an animal. It does not, nevertheless, follow from this, that it contains all the substances in their proper proportions to keep an animal alive; as the reverse is the case. An egg is deficient in water, and in calorific substances, especially of those in the division we call carbo-hydrates—starches, for instance—and these are replaced by the heat that is derived from the act of hatching; and without the shell the egg is also deficient in mineral salts, as these are supplied by the gradual dissolving of the shell which during the formation of the chick continues dissolving until only a thin crust remains.

The white of an egg consists of almost pure albumen,

an exceedingly digestible substance when lightly boiled; but if boiled hard it becomes more indigestible, and is not so readily attacked by the gastric juice.

The yolk of an egg contains about 31 per cent of fat. but it contains also a considerable portion of nitrogenous substances in a highly digestible form.

Eggs get lighter by being kept, because some of the water evaporates through the shell, and air passes through the shell and takes its place. This air that passes into the egg facilitates the process of decomposition that goes on in stale eggs.

A fresh egg is heavier than a stale one. If you dissolve an ounce of common salt in ten ounces of water and place in the fluid an egg, if it be fresh it will sink, but if stale it will float. Sometimes stale eggs will get so light as to float even in water.

Eggs may be preserved in various ways: one of the simplest means is to put them in brine, another to smear them with butter, but it must be borne in mind that they very readily acquire the flavour of the substances in which they are kept.

A fresh egg is also somewhat translucent, and if you look through an egg at a candle the light will get more and more faint as the egg gets staler.

LECTURE XIV.

FOODS AND DRINKS—*Continued.*

WE will next consider the flesh of animals. We may divide animal meats somewhat roughly into what are called red and white. Red meats contain the greatest amount of nutriment in a highly concentrated form, and have a large percentage of nitrogenous substances. White meats are more watery, give more gelatine, contain a less proportion of nitrogenous substances, and as a rule are less nutritious.

Flesh and water would be a sufficient diet to sustain life for a long time, but a very large quantity of flesh would be required to keep up the animal heat.

With red meats we may put those we call butchers' meats, most kinds of game, some kinds of poultry, ducks, geese, wild-fowl, and one fish—viz., salmon. In almost all these cases the animal forms best meat at the middle period of his life. When young the meat is less digestible, and also less nutritious, and when old it becomes hard and tough.

When animals are killed it is the practice to allow as much blood to run out of them as can be got out of the flesh, and you will remember Moses gave particular instructions to the people for whom he made laws that this precaution should be carried out. It is a very wise

practice, because meat will keep very much better if the blood is not allowed to remain in it. One kind of meat which used to be very much prized for its whiteness—viz., veal, was obtained by bleeding the calves before they were killed, which made the meat whiter than it could be obtained in any other way; but this practice has now quite rightly been made illegal.

The characteristics of good butchers' meat are these: it should not be too pale, nor too dark; if very dark it is probably the flesh of an animal that has died, and not been deliberately killed. In the next place, it should be elastic to the touch, so that when the finger is pressed into it the flesh should rebound. Further, it should present a marbled appearance caused by the fine lines of fat between the muscular tissue, and it should not be too moist, especially after hanging, and should contain no trace of parasitic disease.

The meat of an animal that has died is not allowed to be sold for food, and quite rightly, though it does not follow that it is necessarily bad to eat, but it is meat that readily decomposes through the blood having been left in it. It is quite true that when properly cooked, it may not do any harm, but in a large number of instances such meat has produced evil effects, and with regard to some diseases to which animals are subject very serious results have followed the use of such meat as food.

We must make an exception to this rule in the case of some of the diseases of animals which are very widely spread, as a famine might be caused by such a stringent

precaution, and in such cases as the rinderpest and even some parasitic diseases, it may be absolutely necessary that the flesh of animals affected with them should be used as food. In that case special precautions should be taken, such as that the meat is thoroughly well cooked before it is eaten.

Cooked meat is more digestible than raw meat, though by bad cooking it may be made very indigestible. Meat by almost all kinds of cooking loses some of its nutritive qualities, by roasting less than in any other way, because what is lost is chiefly water, and what falls is caught and kept. In roasting meat, in order to keep as much nutritious matter as possible in the joint, it should be put before a good blazing fire in order to harden the outer part, which forms a kind of coating; if put before a slow fire to cook gradually the goodness of the joint is allowed to escape.

Meat loses from 25 to 30 per cent of nutritious substances in boiling. It loses a great percentage of mineral salts, and also soluble nutritious organic substances; these of course get into the water, and so it becomes a consideration whether you want the joint of meat, or the water to be nutritious. Hence if you require as much nutriment as possible in the meat, the proper plan is to put as large a piece as possible into boiling water, which hardens the outside by coagulating the albumen and forms a kind of protecting envelope against the solvent action of the water—and if you want rich broth or beef-tea, the best plan is to cut the meat up into small pieces, put them into cold water and boil

over a slow fire. From this you see it is impossible to have a good piece of meat and good soup from the same joint.

Stewing is a kind of half-way process between roasting and boiling, as the whole of the nutritious substances are saved and served up in the same dish.

Since I have mentioned soup and broth, I may say that the practice of taking soup or broth before dinner which I have seen ridiculed in several books, is certainly an excellent one which has come down to us as the result of long experience. At the time you want a heavy meal you are in need of nourishment, and the soup or broth is absorbed directly by the walls of the stomach and intestines, and gets directly into the blood, and at once begins to nourish the wasted tissues. It has been stated that it dilutes the gastric juice, but that is a mistake, because when it is first put into the stomach there is no gastric juice to dilute: it is secreted afterwards.

Beef is generally accepted as the most nutritious of butchers' meats, and certainly it has the greatest proportion of nutritious substances; it is, however, rather less digestible than mutton, and therefore the latter is more suitable for persons of weak digestion and for invalids.

There have been a few rare instances where mutton was not tolerated at all, and in one instance on record evidently acted as a poison.

Pork is much less digestible, apparently from the close nature of its fibres, and also from the amount of fat that is with it.

Veal and lamb being young foods, are much less digestible than beef or mutton.

The bones of animals are very useful: they contain a large quantity of nutritious substance; gelatine may be prepared from them, and by boiling they make excellent soup.

The viscera of animals are often eaten, for instance the kidneys, liver, part of the stomach as tripe, and the sweetbread. This is more or less a matter of taste, as, on the whole, these are not so good for general consumption as the muscular parts of animals, and they are more liable to contain parasites.

Of game, venison is exceedingly digestible, but it is rather too rich, and is unsuitable on that account for invalids.

The flesh of wild fowl as a general rule is difficult of digestion, and the same may be said of ducks and geese, and in some instances, as in the case of wild duck, it is so difficult of digestion that we are in the habit of taking cayenne pepper with it, in order to stimulate the action of the gastric juice and enable the stomach to digest it.

Pheasants, partridges, and grouse, which are included under red meats, are very digestible. Salmon flesh, however, although nearly as nutritious as mutton or beef, is not quite so digestible.

We will now pass on to the white meats, under which are included ordinary poultry, turkeys, fish, shell-fish, etc. The flesh of the birds yielding white meat is easily digested, and, although very nutritious, the nutriment is not so concentrated as in the case of red meats.

Fish forms a light and digestible food for invalids; but there are some exceptions, for instance the flesh of cod and sturgeon is not very digestible. Fish require to be eaten very fresh, and although the practice of crimping, which is very generally carried out with certain kinds of fish, renders them more digestible and more palatable, it ought not to be done until after the fish have been killed; sometimes they crimp them while they are alive. The flesh of fish contains generally very little fat, but some contain a considerable quantity, and in consequence are less digestible; the liver of the cod contains a great deal, and from this cod-liver oil is obtained.

The flesh of the herring, the eel, and the mackerel, contains fat in the muscular substance, and consequently the flesh of these fishes is rich and difficult of digestion.

The quality of the flesh of fish varies very much, according to the place they come from. You can all understand that fish which have lived in muddy water are not likely to taste as well as those that have lived in clear running streams.

Then among white meats I must mention what are called shell-fish. There are certain crustaceans we use, such as crabs, lobsters, shrimps, etc.; these are an indigestible form of food. Then we pass to molluscs which form an important article of food, especially to certain classes of the community, and the flesh of many of them is very digestible, for instance the oyster, an extremely nutritious food; and in this particular case the flesh is more readily digested when raw than when

cooked, as in the latter case it becomes much tougher. Some persons suffer in one way or another after eating the flesh of some of these creatures, especially after eating mussels, which, for some unaccountable reason, take a poisonous character, and certain instances have occurred of serious illness following their consumption.

These are not by any means the only kinds of white meats that are eaten, as there are locusts, and animals higher in the scale not mentioned before because but seldom used; for instance frogs, and among the reptiles turtles and snakes, and almost all these afford extremely digestible forms of food.

There are several processes in use for the preservation of meat. The decomposition of meat occurs in the presence of air and water, and at a certain temperature, and the processes of preservation for the most part depend upon the exclusion of air and of the substances that air contains, or upon lowering the temperature, or upon drying.

Large quantities of meat are preserved by the exclusion of air. The meat we get from Australia is prepared by putting it in a certain quantity of water in tins, and then subjecting it to a temperature above the boiling point of water, and sealing up the contents while the steam is escaping. In this way air is driven out, and the meat can be preserved for a very considerable time.

Meat may be preserved by drying it, and large quantities of fish are preserved in this way.

In Siberia a mammoth was found in ice, with the

flesh quite fresh and the skin on it, and it was eaten by dogs. It had been preserved in the ice of these frozen regions for probably thousands of years.

So it is quite clear that flesh can be preserved for almost any length of time by cooling it sufficiently, and now that this difficulty has been solved we shall get large quantities of meat from America and other countries, and it is to be hoped that we shall in this way gradually reduce the price of butchers' meat.

Meat may also be preserved by being kept in solutions of substances like salt. The great disadvantage of that is that the brine dissolves out a large proportion of the nutritious substance of the meat; it becomes hardened and much less digestible than before, and when used as daily food is believed to be one of the causes of scurvy.

Then, meats have been concentrated so as to be carried about in a small form, most notably Baron Liebig's extract of meat. This, it has been shown, does not contain the nutritious substances of the meat, and these extracts are more suitable for addition to soups as a flavouring material. The preparation sold under the name of fluid meat, prepared by a process precisely similar to the process of digestion in the stomach, does certainly contain, in a concentrated form, a large proportion of the nutritious substances of the meat.

The attempt has been made to preserve milk by evaporating off a considerable portion of the water and adding sugar, and then sealing up in tins; and in this way milk is preserved in Switzerland and sold here as

condensed milk. It does very well for mixing with tea and coffee, and is better than most foods for children, although they do not thrive as well upon it as upon fresh milk.

I will now mention the important preparations we make from milk. Butter, which you know is made from the cream of milk, consists almost entirely of the fat. Fresh butter contains from 10 to 15 per cent of water, and the remainder is fat, with the exception of a small quantity of caseine—viz., 3 to 5 per cent, and salt is sometimes added, when, of course, we have salt butter. Butter keeps better the less curd there is in it, as the greater the quantity of curd the quicker decomposition sets in. Salt butter may be kept much longer than fresh, but fresh butter may be kept for a long time if placed under water, which is frequently changed, and if a small quantity of tartaric acid be added the preservation is much more complete.

Cheese varies very much according to the amount of cream that is left in the milk from which it is made. For the richest cheeses cream is even added to the milk; for second-class cheeses new milk is used; and cheeses like double Gloucester contain all the fat and curd of the milk. For the poorer cheeses, which are not so digestible, as they offer greater resistance to the gastric juice, and some of them have to be grated to be eaten at all, skim milk is used; these keep much more readily than the richer cheeses, which more easily decompose.

Cheese is an exceedingly nutritious article of food,

and it forms a very important addition to the food of large classes of the community.

It is not a good plan to eat much of a cheese that has been allowed to reach an advanced stage of decomposition, as poisonous effects have resulted from eating cheese in that state.

Let us now turn to *vegetable foods.* The most important of these I have to speak about are the cereals, the grains of which contain substances of great nutritive value; they contain, in the first place, several nitrogenous substances, one of which goes by the name of gluten; they also contain a large proportion of starch, some fat, and some very important mineral salts, especially phosphates.

The first and most important cereal is wheat, which stands in an average position among grains as regards the amount of starch it contains; it contains less than some, but more than others, and a considerable quantity of gluten. Barley is frequently used for making bread, and is especially used for making malt for brewing, and also for making the preparation known as pearl barley.

Oats are still more hardy than barley, and are an exceedingly nutritious food; they contain much fat and a quantity of nitrogenous matter, but no gluten, and so cannot be used for making bread, but their highly nutritious nature makes them a very important food for the inhabitants of certain countries.

Rye thrives on dry, poor, sandy soils in the north of Germany, and is also a very nutritious form of food; but from eating diseased rye certain diseases have been

known to arise and spread among human beings, especially the disease which goes by the name of ergotism.

Maize, a cereal especially cultivated in the New World, but now grown in most parts of southern Europe, in Africa, and southern Asia, contains more fatty matter than any other cereal, and is exceedingly valuable because of the enormous yield that it gives. But this and rice have, unfortunately, to be cultivated in very wet ground, and rice is usually grown in positive swamps.

Rice is the poorest of all cereals ; it contains less nitrogenous substance, and but little of the mineral salts ; it is commonly stated to be the staple food of millions of people, but, being so poor, it requires to be mixed with other things, as milk, cheese, etc.

Several of these grains, notably wheat, are subjected to certain processes for the preparation of bread ; such of them as contain gluten, are capable, when ground up into flour and mixed with water, of forming a mass that will stick together, and can then be made into bread.

For this, either the whole grain may be used or part. The outer part of the grain contains much nitrogenous matter, and a large proportion of salts ; the inner part contains almost all the starch and some nitrogenous matter, more especially gluten ; so you can see if the grain alone is ground up we lose the nitrogenous matter and the salts of the outer part, and for that reason Baron Liebig said that bread should be made from the whole grain, not from the white part alone,

which consists for the most part of starch. He, however, did not take the whole matter into consideration, because, in the first place, if we do not live on bread alone we may certainly choose whether we will eat white bread, or whether we will have brown bread; and, in the second place, it is perfectly certain that bread made out of the inner part of the grain is far more digestible than that made from the whole grain. Brown bread, which formerly was eaten by poor people, was found in the end to be more expensive, because it is not so digestible, and therefore is now usually eaten by the rich rather as a luxury. Brown bread is taken on account of the mechanical action it exerts on the lining membrane of the stomach and intestines; it slightly irritates the mucous membranes, and causes them to secrete their juices more freely.

New bread is much less digestible than that which has been kept a short time, because, when new, it forms a sticky mass in the mouth, with which the saliva is not readily mixed, and so the action of the saliva upon the starch takes place only to a comparatively small extent, and the starch does not get properly digested.

Toast and rusks are very easily digested; as they are brittle and easily broken up in the mouth, they readily mix up with the saliva and get aerated, forming a mass easily digested.

Muffins, crumpets, pastry, and bread insufficiently baked, are very indigestible, from their doughy nature, so much so that some of them go by the name of "sudden deaths."

Bread is aerated by one of three methods, either by yeast added to the dough to set up fermentation, or by carbonate of soda and some acid, such as tartaric or citric acid. It is advisable not to use hydrochloric acid, because it generally contains arsenic, and in some instances bread prepared in this way has actually caused symptoms of poisoning. The third method is that of forcing carbonic acid gas into it, and this forms a very light kind of bread, known as aerated bread, which, however, compared with that lightened by fermentation, is generally considered to be somewhat tasteless.

We use other vegetables for various reasons—some for starch, especially potatoes, yams, artichokes, but most for salts of certain vegetable acids, such as the malic, citric, tartaric, etc.

It has been shown that persons who live on foods that do not contain green vegetables suffer from scurvy, and one of the most important causes of scurvy is the absence of these salts of vegetable acids, and they are often supplied, when vegetables cannot be obtained, by lime-juice.

Just a few words about some substances that we take as drinks.

In the first place, alcoholic drinks. In the last lecture I spoke about the influence of alcohol upon the system. I told you that it was oxidised in the system, and that very little was excreted, but it did not follow from that that it was useful as a food or contributed to animal heat, because I think the balance of evidence shows that alcohol, so far from raising the animal heat,

actually diminishes it, by retarding the oxidisation of other substances.

Strong spirits contain large percentages of alcohol—nearly 50 per cent, and sometimes more than that.

Alcohol acts as a powerful narcotic, and strong alcoholic drinks act in the same way, but in a more deleterious manner, by reason of certain powerful essential oils that they contain.

It has been clearly shown by Dr. Parkes and others that the drinking of strong alcoholic liquors does not enable men to do more bodily work than they would do if they did not take them ; but, on the contrary, that persons who use them cannot do anything like the same amount of work, in the same time, without getting extremely fatigued.

The use of spirits does not enable persons to withstand cold; this is the experience of all travellers in cold countries; neither does it enable them to withstand heat, but, on the contrary, they cannot resist a hot climate as effectually as those who eschew spirituous liquors. We can readily understand this when we consider that the use of strong liquors produces diseases which are common in hot climates—viz., derangements of the liver.

Indigestion is often caused. Spirits act upon the lining membrane of the stomach, and cause sub-acute inflammation, which sometimes goes on to such an extent that occasionally, after a strong dose of perhaps not very good spirits, all the symptoms of acute poisoning, followed by death, are produced.

On more than one occasion I have had the stomachs of persons who have died from drinking a strong dose of spirits, sent to me for examination for arsenic or antimony.

After indigestion, liver disease is produced. The alcohol is absorbed by the capillaries of the stomach and intestines, and conveyed by the portal system through the liver, causing profound alterations there, and an increase of the fibrous structure, which presses upon the proper liver structure, and prevents the liver from performing its functions in a healthy way, impedes the passage of the portal blood, causes dropsy, and ultimately death in one way or another.

These results are brought about all the more surely, because spirits are almost always drunk without food; and whatever one has to say about drinking other alcoholic liquors, it would be an excellent thing if the sale of spirits for drinking were prohibited. Alcohol is very diffusible, gets readily into the blood, circulates through the system, and produces degeneration of the tissues of almost all the organs of the body, including the nervous system, and produces also effects well known to you all in the shape of intoxication, with the crimes which result from it. To sum up about spirits, Dr. Parkes says:—"If spirits neither give strength to the body, nor sustain it against disease—are not protective against cold and wet, and aggravate rather than mitigate the effects of heat—if their use even in moderation increase crime, injure discipline, and impair hope and cheerfulness—if the severest trials of war have

been not merely borne, but most easily borne, without them—if there is no evidence that they are protective against malaria, or other diseases—then I conceive the medical officer will not be justified in sanctioning their issue under any circumstances."

With regard to other alcoholic liquors containing smaller percentages of alcohol, some of them contain as much as 15 or 16 per cent. They all contain considerable percentages of other substances. Some of them, indeed, contain so small a percentage of alcohol, that we must not be in too great a hurry to condemn the use of all alcoholic liquors without inquiring into their action.

The use of strong wines and beers has a tendency to produce the disease called gout, and more especially so when taken in conjunction with highly nitrogenous foods.

With regard to light wines and beers, I do not know that I can do better than read to you what Dr. Parkes says on the subject. Dr. Parkes was a man fully acquainted with this, and indeed with all subjects connected with hygiene, and himself practised total abstinence.

"The facts now stated make it difficult to avoid the conclusion that the dietetic value of alcohol has been much overrated. It does not appear to me possible at present to condemn alcohol altogether as an article of diet in health; or to prove that it is invariably hurtful, as some have attempted to do. It produces effects which are often useful in disease and sometimes desirable in health, but in health it is certainly not a necessity, and many

persons are much better without it. As now used by mankind, it is infinitely more powerful for evil than for good; and though it can hardly be imagined that its dietetic use will cease in our time, yet a clearer view of its effects must surely lead to a lessening of the excessive use which now prevails. As a matter of public health, it is most important that the medical profession should throw its great influence into the scale of moderation; should explain the limit of the useful power, and show how easily the line is passed which carries us from the region of safety into danger, when alcohol is taken as a common article of food."

Coffee and tea contain one and the same essential principle, which goes by the names of theine or caffeine, according as it is prepared from tea or from coffee.

It is a very extraordinary thing that in several parts of the world the natives should have taken parts of different plants to produce beverages, and that the leaves of the tea in China, the berry of the coffee in Arabia, the leaves of the Paraguay tea plant, and some others, should all contain the same essential principle. This fact alone shows us that the principle contained in all these substances must be of some importance and of some use, although it may not be, and certainly is not, a very important element in actual nutrition.

This principle itself is a poisonous substance, but when taken in the moderate quantities in which it is usually taken, it acts as a stimulant to the nervous system without the exciting and depressing effects which follow the drinking of alcoholic stimulants.

It is of especial advantage as a stimulant to the nervous system after fatigue, whether mental or bodily, and it is this particular property of it that makes it especially valuable.

The theine very readily dissolves in boiling water, and so it is necessary to prepare tea with water that is boiling. It is not, however, advantageous to let the hot water stand with the tea-leaves too long, because if it does it extracts tannin and colouring matter, and other things, from the tea. One caution, and that is, that tea causes a very large amount of indigestion. It does not, however, cause a tenth part of that which alcohol causes, especially among the poor classes of the community. This arises, to a large extent, from its being drunk too hot. Our stomachs were not made to hold boiling water, and if people will drink hot water they may be sure that they will suffer from indigestion. Strong tea and coffee should not be drunk with meals, because of their astringent qualities, or, at any rate, only as flavouring materials to milk; and the practice of drinking a small quantity of coffee, with plenty of milk, for breakfast, is a very good one.

Coffee is often mixed with chicory, but if you wish to drink coffee alone, you can buy the berries and grind them yourself. In France they buy the berries and roast them themselves; but in England you can buy roasted berries, and by grinding the berries yourself you get a much better coffee, as some of the essential oils evaporate after the coffee has been ground for any time.

If you buy ground coffee you can tell whether it

contains chicory by putting it in a tumbler of water, when the coffee will float for some time, but the chicory sinks almost directly, and discolours the water much more than coffee does.

Cocoa contains a large quantity of fat, and also a considerable proportion of nitrogenous substance; it is therefore much more nutritious as an article of food than coffee or tea. Its essential principle is closely allied to that found in tea and coffee.

LECTURE XV.

DRINKING WATER.

WATER is one of the most important of our foods, it is a necessity of life to us. Our bodies contain about two-thirds of their weight of water, and the blood contains 79 per cent of it. Water is continually being separated from the blood, and got rid of by the excretory organs, and has to be replaced. If an individual is kept without water he soon becomes reduced to a state of muscular debility, with the greatest possible prostration, the excretory organs begin to lose their power, and he ultimately dies in extreme pain.

The next thing to the use of water as a food is its use for cooking and washing—the domestic uses of water. It is found that if a water supply is deficient in quantity many evils ensue. Food is cooked with the same water twice; people do not wash themselves as much as they should, or in the same water twice, the action of the skin is impaired, the other excretory organs overworked, and so a state of body is produced in which people are very liable to diseases of various kinds.

Besides this, water is used for a variety of public purposes: for cleansing the streets, flushing the sewers, etc., and the absence of water for these uses in a town makes the spread of disease much more easy.

Professor Rankine laid down a rule that thirty-five gallons was the greatest amount necessary per head per day, but that thirty gallons was to be considered a sufficient supply. Many towns have not anything like this amount, but vary from six gallons upwards.

In ancient times and in some modern cities a very much larger supply was and is considered necessary. The supply of ancient Rome is calculated at 300 gallons per head. The ancient Romans attached extreme importance to having sufficient water always at hand. In all Roman camps in this country, if you search you will find that they never pitched a camp for military purposes, except in a place where they could get water either close by or within the camp, and almost always within the camp.

A very remarkable example occurred to me a short time ago. A friend of mine took me up to see a Roman camp at the top of a sandstone hill. It puzzled us to think how the Romans ever got water at the top of that porous hill. We were, however, strolling about, when suddenly I saw half-a-dozen rushes, and that was quite enough to show that there was water. A pocket of clay was there which prevented the water from going down farther, and, no doubt, there was a well at that spot to supply the camp.

We require water of a certain quality for drinking purposes, but we do not require it of the same quality for the other uses.

We might, if it were convenient, have two supplies, one for drinking and another for washing the streets,

flushing the sewers, for baths, and so on. If not, all the water supplied must be fit to drink.

In the first place water for drinking should be clear, it should be transparent and colourless, it should contain no suspended matters in it, and deposit no sediment on standing. It should be aerated, and it should be fresh to the taste, neither salt nor sweet, and should have no smell. Now, if a water does not conform to all these characteristics, it may be said to be water not fit for drinking purposes, but it may, on the other hand, conform to them all and yet not be fit for drinking, for many waters in wells are highly aerated, very sparkling and clear, but are totally unfit to drink, and that is because water may contain matters in solution, and, practically speaking, it always contains matters in solution of one kind or another. It may, in the first place, contain mineral salts in solution to a very considerable extent, sometimes to such an extent as to form petrifying streams or springs.

Water contains most frequently salts of lime, and the salt which is most common and found in the greatest quantities is carbonate of lime. This carbonate of lime, originally in the form of chalk or limestone, is dissolved in the water by means of carbonic acid, which is derived, in the case of rain water, from the air through which the rain passes. The other salts found are sulphate and nitrate of lime, chloride of calcium, chloride of sodium or common salt, and others in smaller quantities, such as salts of magnesia and salts of iron.

From the presence of these mineral salts, either in large or small quantities, waters are divided into two classes—viz., hard and soft. Water that contains a large quantity of mineral salts is hard, and water that contains a small quantity soft.

Besides mineral salts, water may contain in solution, as well as in suspension, organic matters, and among the matters it contains in suspension there may be live creatures, plants and animals.

What is the effect upon health of drinking water containing these various substances? In the first place, waters containing suspended matters are not wholesome waters to drink. They are liable to derange the digestive organs. That is the case whether they contain suspended mineral matters, or whether they contain animal or vegetable matters.

Waters containing a large quantity of mineral salts have been said to aid in the production of calculous disorders, but with regard to waters containing moderate quantities of mineral salts, the evidence goes to show that they are not deleterious to health. It is found that the death-rate in towns supplied with moderately hard water, does not materially differ from the death-rate in a series of towns supplied with soft water. It appears, roughly speaking, that there is no great harm in drinking moderately hard water, if the hardness in the water is due to carbonate of lime, but if the hardness is due to magnesian salts, or other salts of lime than the carbonate, then it is liable to be deleterious, especially to people who are not accustomed to drink

that particular kind of water. And when persons go into a country where the water contains sulphate of lime, as when the water comes from rocks in which sulphate of lime is abundant, for instance around Paris, then they suffer from derangements of the digestive apparatus. Water containing magnesian salts has a special effect which I shall mention shortly.

But another point of view, and an important one, which makes the consideration of the hardness of the water of some moment, is that you cannot make good tea with hard water. You can make very much better tea, and very much easier, with soft water than with hard. Then there is another important consideration, and that is that with hard water an immense amount of soap is wasted, and the soap wasted by the use of hard waters in England is certainly worth hundreds of thousands of pounds sterling in a year. That happens in this way. Soap is a compound of certain fatty acids with soda or with potash, and it has the property of making a lather with water, and we are able to clean ourselves much better with soap and water than with water alone. Now, if I take distilled water, containing no mineral matters at all, and drop into it one measure of a solution of soap of a certain strength, it produces at once a permanent lather, so that this distilled water takes simply one measure to produce a permanent lather, and a small quantity of soap is therefore all that is required. But if I take water containing mineral salts, those mineral salts will decompose the soap, and the lime, magnesia, iron, etc., will combine with the

fatty acids and form an insoluble mass which will not lather with water, and so I have to go on putting soap into this water until all the mineral salts have decomposed all the soap they can, and after that the water will lather, and, in this instance, you see that seventeen times the amount of soap is required to produce this result with the same amount of water, and even now it is scarcely a permanent lather.

The organic matters that water contains in suspension and solution are of much greater importance than these mineral salts. It has been known for a very long time that the water of marshes, when drunk, produces intermittent fever, and that the ague of marshy countries is partly caused by drinking the water of the marshes.

Hippocrates himself, the father of medicine, points out that persons living in marshy countries are liable to have large spleens, which is one of the results of intermittent fever. I can give you a very remarkable instance of this. Three ships started from a place called Bona in Algeria, having 800 soldiers on board—one ship with 120 men. These started from Bona to go to Marseilles. On that ship 13 men died, and of the 107 left, 98 landed at Marseilles with intermittent fever. The other two ships had no cases, and it was found out afterwards that the water was taken for that ship from the district round Bona, and that district is very marshy and intermittent fevers are extremely prevalent there to this day. It was still further found out that the *sailors* on board this ship did not suffer at all, and they were supplied with water which the ships had on board before. It is

quite conclusive that those soldiers got the intermittent fever from the marsh water.

Water that has been obtained from a marsh contains a large quantity of organic matter in suspension and solution, and it is to this, or some part of it, that the disease is attributed.

In 1849 Dr. Snow drew attention to the fact that cholera was spread by drinking water containing the poison of the disease; and after that, in 1854, the celebrated case of the epidemic of cholera in and about Broad Street, Westminster, was investigated, and the results published in a report which, one would think, left nothing to be desired for logical accuracy.

These researches showed that the persons in that neighbourhood who were supplied with water from the pump in Broad Street suffered from cholera, and deaths were almost entirely amongst those persons at the beginning of the epidemic. After the pump was closed the cholera did not disappear at once but after a short time; and an additional proof that this water was the cause of the cholera was afforded by the fact that some persons who went away from the locality, in order to avoid the cholera, to Hampstead and other places, so believed in the water that after they left the neighbourhood they had the water from the Broad Street pump sent to them in bottles, and those persons were the only persons in those particular localities who suffered from cholera. It is only fair to tell you that even this proof has been doubted by the great German hygienist, Dr. Pettenkofer, who, for certain reasons,

throws doubt upon the results drawn from the circumstances I have just sketched out.

However, since that time an epidemic of cholera in the East of London was traced by Mr. J. Netten Radcliffe to drinking water which had not been filtered, and which was shown to have been polluted with discharges from a cholera patient. It has also been shown by Mr. Simon that when two companies delivered water taken from the same source low down in the Thames, the cholera death-rate among people supplied with water by those two companies was practically the same; but when one of these companies moved higher up, and took the water from a less polluted part of the Thames, during the next epidemic, while the death-rate among the people still supplied with water taken from the lower part of the river was very great, that among those supplied from a higher source was very much less.

Glasgow was formerly supplied with very impure water, and during the cholera epidemic of 1832, 2842 deaths occurred; and in that of 1854, no less than 3886. Pure water was then supplied to Glasgow from Loch Katrine; and in 1866, the next cholera year, in that town, instead of 3886 deaths from cholera, there were only 68.

It has been shown in other places, in Berlin, for instance, that the death-rate in houses supplied with impure water is very much higher than in houses supplied with pure water.

So cholera is spread by drinking impure water!

Typhoid fever is a disease which we have come to know much more about of late, and an immense amount of evidence has proved that this fever is spread by drinking water containing sewage.

In a number of instances of this, perhaps one of the most striking is the Millbank Prison. The prisoners used to suffer from a variety of diseases, one of them being typhoid fever. This they got from water supplied by simply drawing water out of the Thames. Since that practice has been discontinued only three cases have occurred, and one at least of these was brought into the prison.

If you read the reports of the Government inspectors upon the places where epidemics of this disease have occurred they all tell the same tale over and over again —polluted water.

Ordinary diarrhœa, too, is frequently caused by it, while diphtheria and sore throat, so frequently produced by breathing foul air, have been traced by some observers to the use of impure water for drinking.

Now, a word or two about the sources of water. Certain accidental sources of water occur. For instance, drinking water has been occasionally obtained out at sea by hanging up blankets which absorb the dew. Melted snow and ice are used in some countries, but the water obtained is not aerated sufficiently, and consequently is bad for digestion, although exceedingly pure.

Rain is the indirect source of all our water supply, and rain-water, when collected away from towns, is very pure soft water; it is therefore advisable to collect

rain-water in country places even for domestic use, and this course is a very good one when there is an epidemic of cholera or typhoid fever. Rain-water, however, collected in and near towns is very impure, almost invariably, from the impurities contained in the air of the towns. This has been especially pointed out by Dr. Angus Smith, who examined rain-water collected in various places.

Rain collected half a mile from the extreme south-west of Manchester, although the wind was blowing from the west, after it had been allowed to clear itself of suspended matters, contained more than two and a half grains of organic matter in a gallon, and was, moreover, obviously impure. It becomes clear, therefore, that rain-water in towns, and for some distance around them, is not pure for drinking purposes.

Shallow well-waters are very liable to be impure, and in towns are almost always impure on account of the percolation of foul matters through the surrounding ground, and are, therefore, unfit for drinking. This becomes a very serious thing when we consider what a large number of our towns are supplied by well-waters.

Water derived from *artesian wells*, that is to say, from wells made by boring down through a series of strata, and ultimately through an impervious stratum into water-bearing rocks below it, afford a very large supply of, generally speaking, very pure and wholesome water; at any rate water which has not been contaminated by foul matters, so that these wells, which

are really supplied with water which has fallen on distant hills, and percolated through the rocks, form an exception, and some of the best water in London is supplied by means of artesian wells.

Spring waters vary very much in the mineral matters which they contain in solution, and they vary according to the kind of rocks from which they come. They are very frequently hard water, but otherwise generally very pure.

River water is very much softer than spring water, but is very frequently largely contaminated with foul organic matter. The towns look upon rivers as outlets for their sewage, and this arises from the fact that the drains which were originally constructed to drain the towns convey the sewage into the rivers, which of course renders them unfit sources for water supply.

But it has been stated that rivers, to a certain extent, purify themselves by flowing, and, in fact, that they purify themselves enough to become a proper source of water supply. There is no doubt that putrescible organic matters are oxidised and rendered harmless in running water, but there is no evidence to show that the poisons of specific diseases are destroyed in this way, and so water that has been once rendered impure ought not to be used for domestic purposes.

Lakes, especially in mountainous countries, afford a very large source of exceedingly pure water, and you have seen the result of supplying one of our large towns, viz., Glasgow, by means of the soft water from a lake.

A word or two about the connection of water with soils.

Waters that come from surface soils are almost invariably impure. So generally are those from loose sand and soft sandstones.

Waters that come from clay soils are generally hard waters, and contain sulphate of lime in solution, and therefore are objectionable, and they also contain large quantities of organic matter in solution.

Waters that come from the chalk and limestone formations are very hard waters, but otherwise are naturally very pure waters; and waters that come from the granitic rocks are, as a rule, soft, and very pure.

Water that comes from soils containing much magnesia produces swelling of the thyroid gland, called goitre, or "Derbyshire Neck." In a few parts of England, in parts of France and Switzerland, and in some other countries, this disease has been traced to drinking very hard waters, and especially those containing magnesian salts.

How is water to be supplied to places? The best plan of supplying it is, as the ancient Romans did, to go to a considerable distance from a place and find water which has not been contaminated, and bring that water to the place where it is wanted.

In the year 92 after Christ, Frontinus, the Roman engineer, described the aqueducts bringing water from various distances to Rome. They brought waters of different degrees of purity, and Frontinus tells us that the purest waters were used for drinking purposes, and

the less pure waters for washing the streets, and for the various other purposes for which pure water was not necessary.

One of these aqueducts brought water for fifty-four miles. Some of them have been repaired from time to time, and still supply the city of Rome with water. And if you go to Rome to-day the first thing that will surprise you is the immense abundance of pure water they have there, and that immense quantity of pure water is brought by some of the aqueducts made by the ancient Romans. They brought spring water from a distance, collected it in reservoirs, let the suspended matters settle, and then distributed the water by pipes to the different parts of the city. They constructed aqueducts not merely for Rome, but for many other great Roman cities. We have been told that the Romans did not understand the first principles of hydrostatics because they did not use inverted syphons for the aqueducts which supplied Rome. They understood them well, for when they had to traverse deep valleys, as at Lyons, they took the water across by means of inverted syphons, and they used precautions which would perfectly astonish you if I had time to tell you about them.

Towns may also sometimes be supplied with pure water by means of artesian wells, but the too prevalent plan of supplying towns with water that we know has been polluted must be condemned.

We will now pass on to consider the methods for the purification of water.

Impure water can be purified to a certain extent,

that is, we can remove certain substances from water, but we cannot tell, so far as known at present, whether we have removed from the water the causes of disease. If we take Thames water that we know has been polluted, we can adopt certain methods for purifying it, and render it much more fit to drink, but we cannot tell whether we have removed from it everything that would cause disease. It must be clear to everybody that in taking impure water and purifying it we are going upon a wrong principle.

Water can be purified on a small scale by boiling it. When you boil water carbonic acid is given off, and carbonate of lime is deposited, and that is why the incrustation in boilers takes place, especially if the water contains much carbonate of lime, so that you can reduce the hardness of water by boiling it, and kill any living things that may be in it. This, however, can only be done on a small scale.

I may tell you that it was noticed during several epidemics of typhoid fever caused by drinking watered milk, that those who drank milk which had been boiled did not get typhoid fever. And boiling water is much more efficacious if an infusion of vegetable substances is made. For instance, in some countries where impure water is generally used, it is drunk in the form of an infusion of tea.

Water can also be softened on a large scale by Clarke's process, which consists in adding lime to the water. Some of you may be astonished at this. The salt that is generally most abundant in hard water is

carbonate of lime; it is dissolved in carbonic acid, not being soluble in water alone. When you add lime it combines with this carbonic acid, and the acid is no longer able to keep the carbonate of lime in solution, and it is then deposited in the form of chalk.

Let us now consider filtration. When water containing substances in solution or suspension is passed through porous materials, it is quite clear that many of the substances that are in suspension will be arrested, and will not pass through, and so the water will be strained; but that is not what is meant by filtration,—it is more than that. When waters containing certain substances in solution are passed through porous materials, if certain conditions are observed, the organic matters that are in solution are altered; they are converted into inorganic substances, and the salts of ammonia that are in solution are also changed; and this change is due to the presence of oxygen derived from air. When organic substances are brought into contact with oxygen, they are oxidised—that is to say, they are decomposed, burned with oxygen, their nitrogen forming nitric acid, and their carbon carbonic acid.

In order that this may take place effectively, the water must flow downwards; it must be poured on the top, and drawn out by pipes below. If the water is forced upwards through a filtering material, this change does not take place. When water is passing through a filter from above, it passes through that material in a large number of small streams, trickling down through the pores of the material; but when it is being forced

upwards through the porous material, it rises in a continuous sheet of water, and simply displaces the air, driving it out; and this is why, when the water is passed downwards, and is brought into contact with the air, such an important change takes place; but when it is passed upwards it is not brought into such contact with the oxygen of the air in the pores of that material, and so such a change cannot take place.

Filtration must be downwards and intermittent; it must not go on continuously.

That is practically the plan which is carried out by the water companies. They allow the water to stand in tanks in the first place, and then pass it over the surface of a filtering bed; it is then collected in pipes below. When this is done it is found that a very considerable amount of purification takes place. Water, when passed through sand or gravel on a large scale, is very considerably purified of organic matters and salts of ammonia.

Water that has been sufficiently purified by being passed through sand or gravel, may become contaminated by the way in which it is supplied.

There are two ways of supplying water, the system of constant service, and that of intermittent service.

With the constant service the pipes are always full, and there is sufficient pressure to take it to the tops of the houses. With the intermittent service, the water is only turned into the pipes for a certain number of hours during the twenty-four, and the pipes during the remainder of the time have no water in them, and so

foul water and foul air get into the pipes, through the joints, from the soil.

With the intermittent service it is necessary to have cisterns, so that water may be stored from one time to another; and these are liable to collect impurities, and so to render the water impure. With the constant system the pipes are always full of water at a considerable pressure, and there is no necessity to have cisterns or butts, except for the supply of the closets, and, consequently, the risk of contamination of the water in cisterns is avoided. Neither can impurities from the soil get into the pipes. It is very important, however, that the water-closets be not supplied directly from the water-mains, for it happens occasionally that the water is necessarily supplied for a day or two on the intermittent system (as, for instance, when a reservoir has to be cleaned out or repaired), in which case foul matters may get into the pipes, not merely from the soil through leaky joints, but directly from the hoppers of the water-closets. This actually happened at Croydon last year, and was no doubt one of the causes of the very severe epidemic of typhoid fever there.

Water, then, from the causes I have mentioned, gets impure, either before it reaches us, or after it is in our houses; it is therefore advisable, as a general rule, to use extra precautions, that the water we drink and use for cooking is pure; and there are various kinds of filters that are much used for this purpose. Their action depends partly, if not entirely, upon the passage of water through some porous material, and most of them depend

entirely upon porous materials to destroy the organic matters in the water.

They are made sometimes of sand and gravel, sometimes of charcoal ; vegetable charcoal has been used, but it is not an efficient filtering medium. Animal charcoal is much better, while it is fresh, and so long as we are certain that it has been well burned ; recent experiments have shown that animal charcoal, when it is not fresh, and is of inferior quality, from one reason or another, becomes a breeding ground for living creatures, and this also happens with a piece of sponge. Sometimes in filters, in order that grosser materials may be kept out, a piece of sponge is used, through which the water flows, and it is frequently found infested with an immense number of living creatures,—hence, these materials for filters are to be condemned.

It is advisable, then, to use as filters substances which are not, from their very nature, liable to become breeding places for animal or vegetable life ; so various kinds of substances which have been thoroughly well burned are used.

The silicated carbon filter is a substance of this kind, and, unlike animal charcoal, is not liable to have in it animal matters, which have not been properly burned. Another substance, having a remarkable purifying power, and highly recommended in the last report of the Rivers Pollution Commissioners, is what is known as spongy iron.

There is a filter, the construction of which is novel ; it is called the aerating filter. The principle of it is

this, that whereas in almost all other filters the air that is driven out comes up through a little pipe, which is made for it, in this instance the air that is driven out of the filtering material by the water as it goes down, is, by a simple and ingenious contrivance, driven up through the filtering material itself; when water is drawn from the filtered water-chamber, the air that has got to come back, and take the place of this water, has to come back through the filtering material, so that that material is being filled with air, whether water is passing through it, or whether water is being drawn out at the tap.

There is a carbon block, through which the water has to pass first, then it goes out below in the form of spray through several little holes, and falls upon another layer of filtering material, through that, and out into the pure water chamber. All parts of this filter can be easily got at, so that it can be cleaned at any time.

LECTURE XVI.

CLIMATE.

UNDER the head of Climate let us first consider moisture in the atmosphere. The air dissolves water just in the same way as water dissolves sugar or salt. The air dissolves very different quantities of water, according to its temperature. Cold air dissolves very little water, warm air dissolves a great deal. Air dissolves water out of all proportion to the rate of the increase of its temperature, so that warm air dissolves a great deal more water than we should expect from its temperature, if we begin by considering how much cold air would dissolve; and so it follows, if you take warm air with water dissolved in it, and cool it, at a certain temperature it will no longer hold all the water in solution, so that some will be deposited; and that temperature is called the dew point. You can prove that by taking a tumbler, and putting a lump of ice into it; after a time water will be deposited on the outside, and that comes from the moisture that was dissolved in the air; the air in the tumbler has cooled the air around to such a degree that it can no longer hold as much water dissolved in it as it held before; and so some of that water is deposited in the form of drops, or, as we call it, in the form of dew.

Now, there are several ways of finding out how much

moisture there is in the air; one way is to weigh the air; moist air, of course, weighs heavier than the same bulk of dry air: but that is a very difficult process. Then there are instruments for directly showing the dew point; these are called hygrometers, by means of which the result is obtained very quickly by calculations from tables, telling how much moisture was in the air at the time of the experiment.

The most widely known hygrometer is that which goes by the name of De Saussure's. I name this particular one because it is one you will recognise at once. Its principle is founded on the fact that a piece of catgut is longer when it is wet than when dry; and so, if you take a piece of catgut, you can make it move a needle as it shortens or lengthens. You will recognise this instrument at once, when I tell you that you have all seen it in the form of a little toy that is sold for telling the weather. You see it very often on mantelpieces—a little house with two doors; a lady comes out in fine weather, and a gentleman in wet. This is produced by the shortening or lengthening of the piece of catgut.

The way, however, in which the amount of moisture is ordinarily determined, is by means of the wet and dry bulb thermometers. This instrument consists of two precisely similar mercurial thermometers. One has some cotton wound round the bulb, the other end of which dips into a vessel containing water; the water rises up the threads of cotton by capillary attraction, and keeps the bulb continually wet. When the air around these two thermometers is saturated with mois-

ture, then the mercury stands at the same height in them both. You will see why, because one is continually moist, and the other is as moist as it can be, because it is in air containing as much moisture as the air will dissolve. But suppose the air, at the time of the experiment, does not contain as much moisture as it can hold, then the moisture evaporates from the wet cotton into the air around. Whenever evaporation takes place heat is required to convert the moisture of this cotton into vapour, which is dissolved by the air around. That heat must come from somewhere, and it is taken from the mercury in the thermometer, which contracts, and therefore falls in the tube. Whenever air does not contain as much water as it can hold in solution, the mercury stands at a lower point in the wet than it does in the dry bulb thermometer.

Now, from the difference in the height we are able to calculate the amount of moisture in the air.

In inhabited places the rule is that the difference between the height of the mercury of these two thermometers should not be less than 4° nor more than 5° Fahr. If less than 4° the air is too moist; if more than 5° it is too dry.

You will see, if you notice the reports in the papers, that the amount of moisture in the air is stated as so much per cent of saturation.

Whenever the air contains as much moisture dissolved in it as it can hold, no matter what the temperature, it is said to be saturated with moisture, and its state is represented by the number 100; and if ever you

see in weather reports, under the head of moisture of the air, the number 100, you will know that the air contains as much as it can hold. The amount of moisture that the air contains when it is not saturated at any given time is expressed in numbers proportional to the ratio between the amount that it does contain and the amount it would contain if it were saturated. Suppose, for instance, it contains half as much water as it can hold in solution, then, no matter what the temperature may be, its state of saturation is represented by 50. So that you see if 80 is represented as the state of the saturation of the air at a certain time on a certain day, you know then that the amount of moisture in the air at that time was $\frac{80}{100}$ths, or $\frac{4}{5}$ths of what it could contain at that temperature.

At 64° Fahr. air will hold in solution $6\frac{1}{2}$ grains of moisture per cubic foot, and if it has that quantity it is saturated.

Now, if on any given day it is found that the temperature is 64°, and there are $6\frac{1}{2}$ grains of moisture per cubic foot, the state of saturation is represented by the number 100.

The freezing point of water is 32° Fahr., and air at that temperature will hold a little over 2 grains of water in solution. If on any day the thermometer is at the freezing point, and the air contains a little over 2 grains of water in each cubic foot, then the saturation of that air is also represented by 100, so that the number 100 means very different things with different temperatures.

As to the influence of moisture dissolved in air—animals in a dry atmosphere lose weight much faster than they do in a moist one. This is because they cannot get rid of moisture by their respiratory organs, or by their skin, fast enough in a moist atmosphere.

Let us consider, first, a moist warm atmosphere. It may be very moist, because warm air can hold a considerable quantity of moisture in solution. On account of the warmth of the air, its lightness, and the amount of moisture contained in it, almost all internal actions go on slowly. Whenever we breathe in light air, we do not at each inspiration breathe in the same weight of air that we do when we breathe in heavy air. When, in addition to being warm, the atmosphere is charged with moisture, the evaporation from the skin goes on to a much less extent, because the air has as much moisture in it as it can have already; less exercise is taken, and so the respiration and circulation go on slower, and blood of an inferior quality is circulated throughout the body, and supplies, among other parts, the nervous system, so that a general laxity and want of tone are the result, which is the state we know as due to the atmosphere of what are called relaxing places, and it is in such atmospheres that certain diseases, especially contagious fevers, spread most easily and rapidly.

If the atmosphere is cold and very moist, most of the moisture is suspended, for the air may not only have moisture dissolved in it, but it may have it suspended in it in the form of mist and fog. Now, the fact of the

air being moist makes it seem colder than it is. It is a universal experience that moist cold air seems colder than dry cold air, which may really be much colder. Heat is more readily extracted from our bodies in a moist cold atmosphere than in a dry one, and there is a difficulty in getting rid of moisture from the respiratory organs and from the skin, because the air is already charged with moisture. On account of this chilly tendency of a moist cold atmosphere, the diseases prevalent in such weather are lung diseases, kidney diseases, and rheumatism.

In large towns the mists and fogs have, besides, special deleterious effects, because they hold suspended in them the impurities of the air—soot, acid vapours from manufactories, etc., and so it is desirable in such weather, especially in large towns, to wear something in the way of a respirator or comforter round the mouth and nose to prevent suspended particles in the air, and even the chilly suspended particles of moisture from getting into the lungs.

With hot dry air we have increased action of the skin, because there is less resistance to the flow of blood in the skin when the air is dry and warm; all the small arteries bringing blood to the skin are relaxed, and the blood also flows quicker in the capillary vessels in the skin. There is a large amount of blood in the skin, and the action of the perspiration glands becomes increased by the excessive amount of blood supplied to them. Evaporation from the surface of the skin takes place very fast, but generally in a hot dry atmosphere it does

not take place sufficiently fast to get rid of the excessive perspiration. On the other hand, the action of all the internal organs except the liver is diminished; for instance, the mucous membrane of the mouth becomes dry, and the same is true of the other mucous membranes, the action of the salivary glands is lessened, and the action of the gastric glands is also lessened; these are some of the most important organs connected with digestion, so that the power of digestion is lessened and the appetite is lessened, because the want of food is less, and so the lessened power of digestion does no harm if we do not try and eat too much in hot dry weather.

The action of the liver is increased in hot atmospheres, and it is well known that liver diseases are prevalent in hot climates.

You will remember I told you there are two reasons why we eat food—the first is to repair the waste of the body which is continually going on, and the second to supply animal heat, which is necessary for our existence, and which is transformed into various kinds of force which we exert. The second of these is required to a much less extent in hot dry weather, because the air around is already so hot that we are not losing heat and may gain it, so we need take little or no food for the purpose of keeping up our heat.

In cold dry air we have precisely the reverse effects. For cold dry air chills the skin, making the small arteries which bring blood to the skin contract, because cold is one of the agents which makes muscular tissue contract;

so the small arteries by which the blood comes to the skin contract and prevent the blood coming to the skin; besides that, the flow of blood in the capillary vessels is slackened in obedience to the known physical law that the flow of liquids in capillary tubes is lessened by cold. Less blood then comes to the skin, and this is very fortunate, because remember that we lose a great deal of heat from the skin, and so the fact that less blood comes to the skin becomes important, for if as much blood came to the skin in cold weather as in warm we should lose heat too fast, and the blood would get chilled too much.

The blood, then, is chiefly in the internal organs, so there is an increased action of the internal organs (except the liver) in cold weather, an increased power of digesting food, and an increased need of food; and in cold weather we eat more than in hot weather, both to repair the greater amount of tissue waste that is going on and to keep up our animal heat.

The diseases prevalent in cold weather are what you would expect from the fact that the blood is thrown from the skin into the internal organs, and the action of the skin is lessened; if the action of the skin is lessened, and the lungs and kidneys have to do some of its work as well as their own, they may get too much to do, and when the blood is thrown back upon them, congestion of one of those organs, and subsequent inflammation, may take place, and lung and kidney diseases are therefore prevalent in cold weather, and so in cold weather we have always the highest death-rates.

When one mass of air containing a large quantity of water dissolved in it meets another of the same bulk which is colder than itself, and they mix, the resulting mixture has the mean temperature of the two masses mixed. Suppose that a mass of air at 32° Fahr., the freezing point of water, meets an equal mass of air at 96°, both being saturated with water, the mass of air at 32° will contain about 2 grains of water, and the mass at 96° about 17½ grains of water in each cubic foot. When these two mix together they form a mass of air having a temperature which is the mean of the two temperatures, namely, 64°. Will that mass of air hold all the water in solution that the other two held? At first sight you might think that it would, but you must remember I told you that air at 64° would only hold 6½ grains per cubic foot, so that when these two masses of air at 32° and 96° mix together, they form a mass at 64°, which will only hold 6½ grains per cubic foot, instead of 9¾ grains, so that the difference of 3¼ grains per cubic foot can no longer be dissolved by the air and it falls; that is the way rain is produced.

The amount of rain that falls varies very much in different countries. Hot air dissolves much more water than cold air, and so the hottest air in the world is likely to have much more water in it than colder air, so the hottest place is likely to have much more rain; thus the greatest amount falls at the equator, and the amount decreases as we go to the poles.

The amount of rain that falls in a place is measured in England in inches. You will see in the reports that

are published in the newspapers that an inch of rain has fallen in a certain time; what does that mean? It means that during the time specified an amount of rain has fallen over that particular place, which, if none of it had evaporated or been soaked up by the ground, would cover that place to the depth of an inch. The amount of rain is measured by an instrument which goes by the name of the rain-gauge. It is a kind of funnel, upon which the rain is allowed to fall; the area of the funnel is known, and it can then be calculated accurately how much rain has fallen in a given time. The chief protection necessary is that the rim of the funnel shall be vertical, so that the drops that fall into it shall not splash out. Let us suppose the area of the funnel to be 100 square inches; when an inch depth of rain falls upon 100 square inches, there will be 100 cubic inches of water; so when 100 cubic inches of water have collected in the vessel below the funnel, one inch of rain has fallen.

The amount of rain that falls in London is from 22 to 23 inches per year on an average. Much more falls in some parts of England, on the west coast of England generally, and in Cumberland as much as 150 inches have fallen. In other countries as much as 400 or 450 inches, and in one place in India 600 inches, fall in a year.

No connection has been made out between the amount of rain that has fallen and the number of deaths in a place, but one thing is certain, and that is, that the rain clears the air. In falling it drags down with it, or dis-

solves, impurities, and so a heavy rainfall tends to purify the air. Another thing that it does is, it flushes the sewers, and so clears out a large amount of impurity out of the drains as well as out of the air. And it has been repeatedly observed that epidemic diseases have disappeared sometimes quite suddenly after very heavy rainfalls. I have always considered it a great advantage in the summer during the prevalence of epidemics of typhoid fever, if we have one or two heavy thunder storms. And it has been noticed over and over again that the mortality from such diseases has been less after a heavy rainfall.

Of the rain that falls upon the ground, part is evaporated, part is absorbed by plants and subsequently evaporated, part runs off the surface, and part penetrates into the soil; the water penetrates through the soil as long as the soil is porous, until it comes to an impervious stratum, along the surface of which it runs until that impervious stratum comes to the surface of the ground, and there the water comes out and forms what we call a spring. The water penetrating the soil dissolves certain matters out of it, and so spring waters are generally very hard waters; sometimes so hard as to be petrifying springs, generally cold, but sometimes in volcanic countries, for one reason or another, they become hot, and may be actually boiling. Springs run together and form rivers, and in so doing a large quantity of carbonic acid, which spring waters contain, is given out into the air, and a good deal of carbonate of lime is deposited, so river waters are generally softer

waters than spring waters, but, in other ways, more impure on account of the impure matters thrown into rivers. Rivers affect the climate of places; thus in their neighbourhood it is cooler in summer than away from them, and warmer in winter until the river freezes. They also affect the climate by evaporation from their surface, and so the neighbourhood of rivers is a moist neighbourhood, and the effluvia which rise from them, especially when a large quantity of impure matter has been thrown into them, are often deleterious to health; but I must tell you that the exact effect of the effluvia given out has not been determined (although they must have an effect), because in all the instances there are so many other causes at work.

Rivers also often influence the climate by inundating the country, and by the large amount of material that they bring down, which they deposit at various parts of their course or at their mouths, so forming unhealthy swamps.

To give you an idea, I will take rather an extreme case, that of the Ganges, which Sir Charles Lyell tells us deposits 6368 million cubic feet of solid matter in a year, and brings down of that more than 6000 million cubic feet of suspended matters during the rainy months.

Considering that two-thirds of the surface of the earth is covered with water, if any difference is effected at all it is clear that a very considerable difference must be made in the climate of places by proximity to the sea.

After height above the sea, the most important consideration, as Humboldt tells us, is the distance from the sea: that happens in this way; the rays of the sun penetrate the waters of the ocean to a great depth, and the heat is, as it were, lost in the body of water; the ocean water has the highest capacity for holding heat, the rays of the sun penetrate to a great depth, and so the water and the air over it are very little heated. On the other hand, the rays of the sun heat the land, which absorbs heat readily, and the air over the land gets heated during the day, so that during the day the air over the land and the land get hot, and the air over the sea and the sea are very little heated, and so the pressure of the air over the sea is greater than over the land, therefore, during the day the breeze blows from the sea towards the land. During the night the earth gets very cold; the sea does nothing of the kind; it radiates very little, and so the sea and air over it change very little in temperature between day and night; during the night, therefore, a breeze blows from the land towards the sea. So the farther the land is from the sea the less it is affected by the change of air due to proximity to the sea. The sea exercises an equalising influence over the temperature of the land, and places near the sea have an equable temperature.

London is a good deal north of Paris, but it is near the sea, so London has a comparatively equable climate, while Paris has a climate of extremes, a very hot summer and a very cold winter. Paris sometimes has very cold winters indeed, on account of its distance

from the sea. The Channel Islands, on the other hand, are very equable in climate. So places near the sea have the advantage of having their air changed very frequently, and it is, I make no doubt, one of the reasons why London and its neighbourhood are naturally such healthy places.

The sea air contains a large amount of moisture, as you would expect, dissolved in it, and sometimes suspended in it, and so places near the sea-side are moist places, and places which are exposed to winds passing over a large area of sea are moist places. That is why the west coast of England is moister than the east.

Diseases like dysentery, plague, cholera, ague, and so on, do not travel across even very narrow pieces of the sea, and so it is the habit in countries where these diseases are prevalent to have hospital ships placed at a little distance from the coast, and it has been frequently noticed, that while troops on land have been decimated by some of these diseases in hot climates, the sailors in the harbours have not suffered at all.

A word about stagnant waters.

When I tell you that two-thirds of the Europeans who die in hot countries, die of diseases that have been generated in marshy places, you will understand that it is an extremely important matter. When you consider that the oriental plague, which killed so many millions of people in the middle ages started in the marshes at the mouth of the Nile—that cholera commenced in the marshes of the Ganges—that yellow fever commenced at the mouth of the Mississippi—and that various kinds

of ague are prevalent in marshy countries of all the temperate climates in the world, and extremely prevalent in many parts of Europe, you will see that this matter is one of great importance. Marshes may be found wherever a somewhat impervious soil exists, so that the water cannot get away by natural drainage; it does not at all matter how the water gets there: it may get there by rain, by the usual overflow of the river, or by the flow of a river being obstructed by the deposit brought down by it, for great rivers frequently bring down much solid suspended matter. In each case the result is the same, there is stagnant water, profuse vegetation, and one or other of these pestilential diseases is engendered, the worst forms of these diseases being found in the marshes of tropical climates. The precautions which people who work in marshy countries, for instance in cutting down forests or making railways, should take are—that they should live on as high a piece of ground as they can get; the windows should be away from the prevailing wind, especially if it blows over marshy land: they should never sleep on the ground, as it has been noticed over and over again that persons sleeping on the ground are much more liable to get such diseases than those who sleep even in hammocks above ground; they should eat moderately, and especially of well-cooked food,—should not drink water from the marsh, or if they must do so, should boil it first, or, what is still better, should make tea of it.

In many instances the marshy country itself may be made salubrious, and this has been done on a large

scale all over the world; Lower Egypt is one of the most remarkable instances of this. Lower Egypt used to be most fertile and prosperous—it was the place from which all the arts and sciences originated, the place in which medicine was first cultivated, and in which attention was first given to sanitary science. Moses, who was "learned in all the wisdom of the Egyptians," gave us the most admirable code of sanitary laws ever issued. Lower Egypt was the place, indeed, from which started all our knowledge; a highly intellectual race inhabited it at one time. Later on, through neglect of drainage, it became the most pestilential swamp, the home of the plague, which ravaged the whole world.

Intermittent fevers used to be much more fatal in England than they are now. The Registrar-general, I see in his summary for ten years, draws attention to this fact, which is the result of increased drainage of soil, so that there is no doubt whatever, that by drainage, the death-rate from marshy diseases may be lessened to a very considerable extent.

I said that, according to Humboldt, height above the sea was the most important fact as regards the climate of a place, and the higher the place above the sea, the lower its temperature, until at last we get to the region of perpetual snow. You think it is a strange thing that the higher and nearer to the sun we get, the more the temperature is lowered, but the reason is that the air is so rare that it does not absorb the sun's rays; they pass through it. The higher you go the rarer the air is, and so each time you breathe you breathe in the same volume

but less weight of air, and therefore less weight of oxygen, so in order to get the amount of oxygen which is required for the purposes of the system you have to breathe more times, and people who live high above the sea level always breathe more quickly, hence those who require their lungs exercised adopt the excellent plan of going up into the mountains.

The diseases prevalent in mountainous countries are those due to cold, such as lung diseases, rheumatism, and heart disease consequent on rheumatic fever, but they are more specially prevalent, not in exposed situations but in gorges and valleys, where the air is stagnant and damp: cholera and typhoid fever are rare in mountainous countries, and in many such places cholera has never appeared at all.

Cold, then, is an important consideration, and this leads me to say that things made of wool are warmer, because they allow less heat to get away from the body, and another reason is that they absorb the moisture of the skin much more readily than clothes made of cotton or linen.

Land which is covered with vegetation, other things being equal, is colder and moister than dry places, for we know that dry places when there is no vegetation at all are some of the hottest places in the world, as, for instance, the desert of Sahara.

A word or two about the condition of the soil itself. Soils may be divided roughly into pervious soils and impervious soils. Places built upon pervious soils such as gravel, sand, chalk, through which the water can

penetrate are dry, and generally healthy: lung diseases, rheumatic diseases, and consumption, are less prevalent there. The diseases that are prevalent there are cholera and typhoid fever; they spread upon these soils, according to the theory of a great German hygienist, on account of the emanations which are given out of these soils under certain circumstances, but in England we believe that these diseases spread because people drink water from wells in the soil into which impurities have percolated.

Upon impervious soils the disease that is especially prevalent is consumption, and on all undrained soils, whether pervious or impervious, this disease, the plague of temperate climates, is prevalent. Dr. Buchanan has shown that there are no instances among the cases investigated, where the level of the water in the soil beneath the houses has been lowered by drainage, in which the death-rate from consumption has not been lessened, and in one town in England it was lessened fifty per cent. Various lung diseases and rheumatic affections are also prevalent on damp soils. It is exceedingly important that we should live upon dry soils, and there should be in every house what is called a damp course, a little distance above the ground all round the wall, of asphalte or glazed stoneware, so that the moisture cannot rise up through the walls. It is very important, too, that the basement of all houses should be impervious to water; there should be a layer of asphalte or concrete, all over the basement floor, above which the boards should be laid, and, if possible,

there should be a ventilated air-space between the floor and the asphalte or concrete, so that no damp can rise up into the house; another reason for that is, that all soils contain a certain amount of air; pervious soils contain a good deal, and that is air which should not be admitted into the house, as it contains a large amount of moisture and organic matter, which may be very foul.

LECTURE XVII.

HOUSES AND TOWNS.

WE will now consider the sanitary arrangements in houses, and to a certain extent in towns also.

I will first say a few words about water cisterns.

With the system of constant service there is no need to have cisterns for drinking water, and that is one of the great advantages of the constant service. But with the system of intermittent service the drinking water must be stored in cisterns.

The first thing to be considered is the material of which the cisterns are made—wood, stone, slate, lead, or iron. Wooden ones are clearly open to many objections and not very much used. In some houses of the poorer classes casks and tubs of wood are often used for water.

Stone cisterns are too heavy for use, in any other situation than in the basement of a house, and though they are excellent cisterns, they are useless for general purposes above the ground floor.

Slate cisterns are often used, and were much recommended some time ago. They have some disadvantages: the first is their weight, the second is that the joints are apt to become leaky, and I believe, although several reasons are given for this, the true reason is that more or less vibration is continually going on from the traffic

in the streets, and perhaps proximity to railroads, which is sufficient to weaken the joints of these heavy slate cisterns, and they always leak after a time. When this happens, the man sent for is the plumber, and he very naturally empties the cistern, gets into it, and fills up the joints with red lead.

Leaden cisterns and leaden pipes are very largely used—I think even more largely used than any other kind. Some time ago there was a considerable outcry against leaden cisterns and pipes, because certain waters dissolved the lead and became poisonous ; the outcry was perfectly just, because we are not justified in running the risk attached to leaden cisterns and pipes, unless we know that the water we are to have in them will not dissolve the lead. I said that they are very largely used, and the reason is that it is found that the majority of waters supplied for drinking purposes do not affect lead, or if they do affect it, only do so for a short time, and an insoluble coating is formed on the surface of the lead inside the cisterns and pipes, which renders them proof against further attacks of the water, so practically as a matter of fact we are not poisoned, although nine out of ten people drink water out of pipes or cisterns made of lead. Waters that attack lead best are very soft pure waters; rain water, for instance, attacks it with great rapidity ; that is not the kind of water we are supplied with for drinkiug purposes.

Waters containing certain salts have very little action on leaden pipes and cisterns, but it is clearly wise if any other material can be found which possesses most of

the advantages of lead, and not the disadvantage, to use it.

The advantages of lead must be clear to everybody. It is a material very easily worked, extremely lasting, and, as far as pipes are concerned, can be bent in any direction with the greatest facility, and joined with a perfectly water-tight joint.

The material that is now replacing lead for the purposes of cisterns and pipes is wrought-iron. Some years ago the use of wrought-iron pipes for conveying water came into fashion, and they are being used more and more. They have the advantage of being cheaper than lead, and are very durable. The disadvantage they have is, that the iron is not so easily jointed, and bends have to be made of every kind, because the metal cannot be bent. Wrought-iron cisterns, especially galvanised wrought-iron—that is to say coated with a layer of zinc—are becoming very much used indeed for water cisterns, and they are the best kind of cisterns we have at present. It is quite possible that Professor Barff's invention of indestructible iron, a process by which the iron is coated with an absolutely unalterable layer of oxide, will come into use for cisterns and water-pipes, as well as for many other things.

Excellent glazed stoneware cisterns are now made cheaply enough for use in the poorest dwellings.

We assume, then, that it is necessary to have a cistern to supply the drinking water of the houses, and the first thing to be careful about with a cistern is, that it must not be used for any other purpose. You must

not have one cistern to supply the water for drinking, and for every other purpose for which water is required in a house. That is an exceedingly important thing, because, in some way or another, if the cistern is used for the closets as well, the water may get contaminated, and become unfit to drink. It has been argued that by a proper arrangement of taps and pipes, you can make it almost impossible that this shall take place, but if you cannot prove an instance to the contrary, you may always meet such an argument of that kind by the assertion that it is going upon a wrong principle altogether. Even if you cannot see how the water can be contaminated, that may be because you are not sufficiently experienced; but, however great your experience, you are perfectly safe in asserting the belief that it is going upon a wrong principle.

The water-closets may, however, be supplied by subsidiary cisterns, fed from the one main cistern. Cisterns are supplied with water by means of a tap, which goes by the name of the ball-cock or ball-valve, from having attached to it a hollow copper-ball filled with air. The water, as it comes into the cistern, raises up the ball, and the cistern is filled to a certain height. As soon as it has reached a certain point, the ball rising closes the valve. Supposing that this ball-valve does not act for some reason or another (and you must always, in all contrivances, provide for their getting out of order), as from rust, which prevents the ball rising easily, the water rises, and the ball remains sunk, then the valve does not get closed, and you have

the house flooded, unless you have some contrivance by which the water can get away. So, too, suppose the ball does float, and does rise, and from the tap having become worn out the water does not get quite turned off, or if turned off, yet the water continues running, then you will have the water overflowing into the house, unless you have some arrangement to prevent such a disaster. Well, that contrivance is provided by means of a waste-pipe, or overflow pipe, as it is called. It is generally placed near one corner of the cistern, beginning just above the level of the water when the cistern is full, and it comes down through the bottom of the cistern, so that whenever the water goes on running, as soon as it gets up to the level of the top of the waste-pipe, it flows over and runs away.

Now, a most important question is, Where does the waste-pipe go to? In almost all old houses in London the waste-pipe, even if the cistern be at the top of the house, goes straight down through the house into the drain below. It does so in many new houses, and when it does not actually do that, it very often goes into one of the pipes leading into the drain.

Now, the cistern is commonly covered over, and rightly so, to keep it free from dust, and so you see the air over the water in the cistern is placed in direct communication by the waste-pipe with the air in the drain; and in a very large number of houses the only way that the foul air can get out of the drain at all is by getting up the waste-pipe of the cistern, and so the foul matters are absorbed by the drinking water, and it becomes foul

and unfit to drink, the result being disease in the household. I am convinced that the greater proportion of cases of typhoid fever in London are caused by the air of the drain getting into the drinking water cistern.

How can this be prevented? It can be avoided by making the waste-pipe end anywhere except in the drain. It does not matter much where it ends. It is only of use when there is something wrong with the ball-cock, so that the water overflows, or when it is necessary to clean out the cistern, which is done by taking out that part of the pipe which stands up in the cistern, letting the water run away, and then cleaning the cistern out down the waste-pipe. This pipe should be made to end somewhere out of doors—say over the yard or over the top of a rain water-pipe, or on the leads or the roof. Take it straight through the wall, and let it end in the open air.

Sometimes, instead of a waste-pipe of that kind, an opening is merely made in one side of the cistern above the level of the water, and then if the water ever rises up to that it flows over on to the roof or on the leads, and if the cistern is out on the leads this is all that is necessary.

I have seen sometimes, with a cistern out of doors upon the leads, the waste-pipe taken through the bottom, down through the rooms below, through the basement, and into the drain or sewer below the house.

There is a cistern which is called the self-cleansing cistern, the bottom of which slopes in all directions to-

wards the middle point, and at that point the waste-pipe is placed, and it is a waste-pipe that can be lifted. At or just above the level of the water when the cistern is full, there are holes in the waste-pipe, so that whenever the water rises higher than it should be it flows away through the holes down the waste-pipe. By means of a lever, which is fixed to the waste-pipe above the cistern, the pipe can be raised out of the socket in which it fits, and then all the water runs out of the cistern, and as the bottom of the cistern slopes towards the aperture in the middle, the water flowing away washes out any sediment there may be.

It is now a very common practice to have a filter in the cistern to prevent suspended particles in the water from being drawn off at the tap, but I must tell you that most of these filters do very little else than prevent suspended matters from getting into the water drawn, because they cannot be sufficiently aerated. There is one disadvantage to this plan, and that is, that whenever the tap is turned on, there is a suction of water towards the filter, and the suspended matters in the water get attached to the outside of the filter. In some the water is made to pass through a piece of sponge, which, after a time, becomes full of impurities, and the water is worse after passing through it than before.

There is a device by which the water is admitted through a tap, carried down by means of a pipe into a circular space which is outside the filtering material, but yet separated from the water in the cistern, and passes out at another place, so that it continually

washes the surface of the filter, while a certain portion of it passes through the filtering material, and so into the compartment from which filtered water is drawn by the tap.

There is another thing worth bearing in mind, and that is, that a filter in a cistern requires air, because, when you are drawing off water from the tap, you are drawing it off faster than water can come into the filtering material, so air is allowed to come in through an air-pipe into the filtering material. Another advantage that that air-pipe has, is that the top of it can be connected with the water-tap, and so water can be driven by means of it through the filtering material, so as to cleanse it.

Among refuse matters that have to be removed from habitations there is first what is called *dust*. You know, in most of our large towns, it is collected in receptacles of some kind or another.

Two or three things to be said with regard to the place where these should be. In the first place, they ought not to be built against the walls of dwelling-rooms, as the rooms may be rendered unhealthy without being rendered damp, and I have known many dwelling-rooms rendered very unhealthy by the dust-bins being built against their walls. The next thing is that nothing except ashes should be thrown into the dust-bin. All organic kitchen refuse ought to be burnt, and not allowed to accumulate. If put into the dust-bin it certainly becomes a nuisance. It can be burnt if it be thrown on the kitchen fire the last thing

at night, when the kitchen fire has just been allowed to go out, and it will dry gradually during the night, and can then easily be burnt in the morning, and no kind of unpleasantness is caused if this is done regularly every day. It is as necessary also to remove refuse matters generally from the neighbourhood of habitations, as it is to get rid of refuse matters from our bodies.

We, as you know, are continually separating out from our blood impurities, and we ought to as regularly get rid of all refuse matters from the neighbourhood of our dwellings.

If not got rid of they produce disease, and in every place where refuse matters are not got rid of speedily, there is a high death-rate, and especially a large proportion of deaths among infants.

These refuse matters get either into the water which is drunk, or into the air which is breathed, or into both, and cause a general low state of health. The effects on the death-rate of infants are bad, because infants are peculiarly susceptible to disorders caused by foul organic matters. Cholera and typhoid fever are diseases which especially prevail in communities where the refuse matters are allowed to accumulate in and about the houses.

There are a great many plans by which refuse matters are removed from houses and from towns. There are, however, two particular systems—the first of which goes by the name of the conservancy system, and the second by that of the water-carriage system.

The name of the conservancy system condemns it at once—I have told you it is of the first importance for the health of the community that refuse matters should be removed from habitations—as it shows that the very principle upon which this system depends violates one of the first laws of health, viz., that refuse matters ought not to be kept or allowed to accumulate in the neighbourhood of habitations.

A great many plans have been tried: sometimes refuse matters are collected, as in Edinburgh, without anything being mixed with them at all; sometimes they are collected and mixed with the ashes provided by the fires; sometimes they are collected and mixed with dry earth, according to the dry earth system brought into notice by the Rev. Henry Moule; sometimes they are collected and mixed with a deodorising or disinfecting substance; but whatever the plan is there is the same mistake all round—they are kept in or about the houses as long as they are not a nuisance; that is the theory upon which these methods all go. It is essentially a wrong principle; in a certain number of instances they will be kept until they are a nuisance, and necessarily kept, therefore, until they are poisonous. And you can see, also, that an enormous disadvantage in these systems is the expense of cartage—the expense of carrying the refuse matters away; and in the case of the dry earth system there is the additional expense of collecting the earth, drying it, and carrying it into places that are to be supplied. You can see at once, for these systems to work economically, it

is advantageous to leave the refuse matters in and about the habitations as long as possible, because the less it is necessary to send round carts to collect it, the less expense the arrangement will entail; so that all these plans, if they are carried out economically, are more likely to be injurious to the health of the community; and in all towns in which refuse matters are disposed of in this way, although it may happen that the system as now carried out is better than the systems which were carried out ten years ago, still in all towns where refuse matters are left for a certain time, and carried away bodily, there is a high death-rate, and a comparatively low condition of health. Now, these systems, including the dry earth system, are none of them fit for towns, but they are suited, under certain circumstances, for small villages, and for large temporary gatherings, such as cattle-fairs, horse-shows, etc., and for places where special and particular attention can be given to them; but they are not suited for use in the midst of large collections of human beings.

We will pass on to the consideration of the system which is in use in London—the water-carriage system. With any system you must have pipes to get rid of the foul water, and in ninety-nine out of a hundred cases it is a great advantage to get rid of all refuse matters at once, and for that reason the water-carriage system commends itself.

One of the reports from India on the dry earth system, which has been carried out there very largely, states that in every well-organised community—they

are speaking of barracks, and what is true of them is also true of houses and towns—the foul water that has to be got rid of is to the refuse matter that can be removed by the dry earth system as 190 is to 1. It is perfectly absurd to have two systems, one to carry away foul water, and another to carry away foul refuse matters, bearing the proportion of 190 to 1. Foul water has to be got rid of from houses, and so we must have pipes to get rid of it. These pipes we call sewers. The foul water must not be allowed to get out of the pipes into the soil below the houses, and so they require to be made water-tight; it will not do to have the sewers below the houses (commonly called the house drains) made of bricks, or other pervious materials, as was the case with all the old house drains of the metropolis. Drains or sewers to carry away foul water require to be impervious in order that the water may not get out into the soil; they are now commonly made of the material known as glazed stoneware, with socketed joints carefully cemented; thus the foul water can get away from the houses by these pipes without getting into the soil underneath, and without getting into the water if the house is supplied by a well.

The pipe that conveys foul water away from the house must end in the common sewer of the district, and where it joins the street sewer a very common plan, and not at all a bad plan, is to put a heavy metal flap hung on hinges at the mouth of it; the foul water running down from the house pushes open the flap and falls into the sewer, but as soon as it has done running,

the flap shuts. That simple contrivance works very well so long as it is in order, and it can be examined from the inside of the sewer; it is used very largely in London.

Upon the house sewer it is usual to put some kind of water-trap. Now, the water-trap, whatever be its form, and there are a great many varieties, is essentially a bend in a pipe which will hold water; the simplest is the so-called syphon, or U shaped bend; when water is poured down it will remain in the bend up to a certain level, so that the water will prevent air from coming into the house through the pipe, from the sewer. But remember always this, that water-traps are things that cannot be relied on: they will prevent great draughts of air from coming out of the pipes when there is water; but suppose there is water in them, then foul matters in the air on one side are absorbed into the water and given out from the surface on the other side into the house; that has been shown perfectly clearly by experiment. Matters of various kinds can be absorbed on one side of the water-trap and given off on the other side, so that you cannot rely upon water-traps alone to prevent foul matters in the sewers getting up into the house. You must rely on something else, and that is ventilation, a means of escape, or, if possible, a forced escape, of the air from the sewer into the open air, so that from every house sewer there ought to be one or more four-inch pipes rising up outside the house from the highest points of the sewer, and going above the tops of the houses into the open air. These pipes may be continuations of the soil-pipes, but must not be rain

water-pipes unless the top of these pipes is at a considerable distance from any window.

It is frequent now, and a very good practice, to make an air opening at about the level of the ground, leading into the drain just on the house side of the trap which separates the drain or house sewer from the main sewer, and this is a very good plan provided the opening is not too near to a window, as where it is adopted foul air cannot accumulate in the drain.

I have already spoken about the waste-pipe of the cistern, and that ought always to end outside the house in the open air. The other pipes that ought to end in the same way outside the house, and that very seldom do, are the waste-pipes from the sinks, from the bath, and all waste-pipes of that kind; they all, as a rule, go into the drain. You will say, if you allow these pipes to end over the yard, the yard gets into a great mess, but then that is better than to have half a dozen pipes going into the drain, and allowing foul air to get into the house through them. You can, however, avoid that in several ways. There must be some kind of trap to carry away the rain water. Now, sometimes the syphon trap is used, a trap with an open gully, and then a syphon-pipe leading from it, so that it holds water up to a certain level, and a very excellent kind of trap it is. If you want to make a sink-pipe or bath-pipe end away from the drain, you need not have the end over the surface of the yard, but you can have one of these syphon-traps with a hole in the side which is above the level of the water in the gully, so that the waste-

pipe comes in under the grating, but above the water in the trap, and is thus completely disconnected from the drain.

In order to prevent foul-smelling air coming up sink waste-pipes, it is well to have a trap of some kind below the sink, not for the sake of keeping out drain air, but for the sake of preventing a draught from coming in tainted with foul matter from the waste-pipe itself. There ought, then, to be a syphon-trap immediately below the sink, and it is a good plan to have one with an opening closed by a screw cap for the purpose of clearing the trap in case it should get stopped up. Sometimes what is called a D trap, from its shape, is used for this purpose. The pipe ought to be carried through the wall and made to end in the side of a syphon-trap underneath the grating, but above the level of the water in the trap, so that practically the pipe is cut off from the drain. For downstairs sinks there is a trap which does admirably well, and requires no trap to be placed upon the sink-pipe; it is called the Mansergh-trap. The sink-pipe goes in through an aperture in the side of it into one compartment, and is turned downwards, so that the sink-pipe is trapped itself in the water contained in the first compartment; then the water flows from the first compartment through an aperture into the second compartment, and over these two compartments there is a loose iron lid with openings in it, and then from the second compartment the water flows under a partition into a third, which is closed, and from the third compartment it

flows through an outlet into the drain, and there is another outlet in the third compartment to which a ventilating-pipe may be attached.

I warn you against having openings of any kind into the drains from the basement. It is a very common thing to have a trap under the tap for the kitchen boiler, leading into the drain; these are most dangerous things to have. If the sinks, baths, and waste-pipes are cut off it is perfect folly to have traps in the floor of the house connected with the drain, and the greatest danger of all is to have a trap of the kind commonly known as the bell-trap, in the floor of the house connected with the drain; it is one of the worst contrivances ever devised, and has no redeeming point. It consists of an iron box through the bottom of which a pipe passes to the drain; the cover is a perforated plate which has a bell-shaped piece of metal fixed into its under surface; when the cover is in place the bell is immediately over the top of the pipe which projects above the bottom of the box, and the rim of the bell dips into the water, which of course stands in the box at the level of the mouth of the pipe. The disadvantages it has are: that the water is only about half an inch deep, so that the pressure of the air in the drain is often sufficient to drive the foul air through that small quantity of water; the difference between the temperature of the air in the kitchen and that in the drain is sufficient to cause this foul up-draught, especially when some of the water has evaporated; and that whenever the top is removed the trap is gone,

and these traps do not let the water run very readily, consequently the trap is frequently taken up, and the foul air gets into the house, causing diarrhœa, typhoid fever, and so on.

Water-closets should be of as simple a construction as possible; hopper closets with flushing rims and 1¼-inch supply-pipes are well suited for general use. Pan closets are bad contrivances, on account of the large iron "container" which always becomes foul; valve closets are far better. D traps should never be used, but always S or P traps, and when a leaden tray or "safe" is placed under a water-closet or a bath, the waste-pipe from it must go through the wall into the open air, and not be joined to the closet trap.

With regard to sanitary matters connected with towns, all sewers of towns ought to be well ventilated at the level of the streets, else foul air will come from them into the houses. The common sewers of towns ought always to end freely; if they end under the level of the sea or of a river, the water will be backed up in them some time or another, and foul air will be produced in the sewers and spread disease in the town. The only instances in which adoption of the water-carriage system in towns has been attended with an increase in the death-rate from typhoid fever have been instances in which the common sewer has ended under water. In all other instances, without exception, where the water-carriage system has been introduced, the death-rate from this fever has been diminished, and cholera abolished. What is to be done with the sewage

from the towns? It is commonly turned into rivers. The Romans found out how convenient the drains were to convey refuse matter away from the towns, and the natural place to end the drains was the river, and that is why our sewers now in the great majority of cases end in the rivers. The evils of this are that the sewage makes the rivers foul, renders the water unfit to drink, and, in the case of small rivers at any rate, the sediment blocks up their course.

Sewage should be got rid of upon the land, and although there are very great difficulties in the way of it, I can safely say that there is no other system that has been suggested which is capable of purifying sewage water. Irrigation farms should be carried out upon the principle of downward filtration, and though it is the exception for them to be made to pay, still I think you will all agree that if it is the best way by which this water can be purified, so that it shall be fit to run into the streams again, it ought, whenever practicable, even at a certain amount of expense, to be carried out, and if we cannot make it successful from a monetary point of view, we shall most certainly derive from it very valuable crops of grass, which forms excellent food for cattle to supply us with milk, the food which is specially needed for the children in all our large towns; one of the most important causes of the great mortality among the children in our towns has been shown to be due to the want of milk for them, and this want may be most certainly supplied by large grass farms irrigated with the foul water from our large towns.

LECTURE XVIII.

SMALLPOX.

I AM going to speak to you this evening about one disease. If you ask why I single out this disease from all the rest, I do so because it is, as is acknowledged by all who know anything about the subject, the most fearful disease that has ever afflicted the world, namely, SMALLPOX.

Now, in order to give those of you who do not know what this disease is an idea of it, I should like to read the eloquent words of Dr. Parkes:—"Smallpox is now so seldom seen that there must be millions of people who have no true idea of it, and do not know its history. It is, in my opinion, the most frightful malady which afflicts us. To see a bad case of smallpox, the thick crust of eruption masking the entire face and head; the swollen, distorted features, which make the person unrecognisable; the closed eyes, half glued together by matter, and the swollen, open, dribbling mouth; the swollen, nerveless, shaking hand; all form a sight never to be forgotten; and whoever has seen this can see, except leprosy, few things more loathsome. And when it is also found that this disease is in the highest degree contagious, and is caught most readily from person to

person, nothing is wanting to give it the first rank in the horrible incidents of life."

I should like also to give you a little idea of what this disease is when introduced into a community for the first time, and I will read to you some extracts from Dr. Guy's excellent little work on Public Health.

"Here is what Alexander Mackenzie says of the disease as it attacked the North American Indians. It was as a fire consuming the dry grass of the field. The infection spread with a rapidity which no flight could escape, and with a fatal effect which nothing could resist. 'It destroyed with its pestilential breath whole families and tribes.' After picturing the scene presented by the dead and dying, and the putrid carcasses dragged out of the huts by the wolves, or mangled inside by the dogs feasting on the disfigured remains of their masters, he finishes by telling us that it was not 'uncommon for the father of a family, whom the infection had not reached, to call them around him, to represent the cruel sufferings and horrid fate of their relations from the influence of some evil spirit who was preparing to extirpate their race, and to incite them to baffle death, with all its horrors, by their own poniards. At the same time, if their hearts failed them in this necessary act, he was himself ready to perform the deed of mercy with his own hand, as the last act of his affection, and instantly to follow them to the common place of rest and refuge from human evil.' To the same effect is the Rev. Mr. Cordiner's description of

the ravages of the smallpox in Ceylon, where, according to a very moderate calculation, it carried off a sixth of the inhabitants. We are told that the disease inspired the people with such terror that husbands forsook their wives, and parents their children, leaving them only a little drink and food; that wild beasts attacked and destroyed the abandoned villages; and that not even the bones of the deserted sick were afterwards to be found."

I will give you one more case of the same class. "A Dutch ship, with smallpox on board, put into the Cape of Good Hope, and the captain sent the foul linen ashore to be washed. The smallpox broke out among the Hottentots who washed the clothes, and killed most of them. It then spread up the country to such an extent that the native tribes at last drew a cordon round the infected places, and shot all who tried to pass beyond it. This fact, cited from Dr. Mead, affords a good illustration of the liability of the disease to be conveyed in articles of clothing."

This disease is no respecter of persons; it is recorded that the father, the mother, the wife, an uncle, and two of the cousins of our King William the Third died of smallpox, and that he himself was severely marked with it.

In the last century, in England, there were thirty-four decided epidemics of smallpox, or about one every three years; and during that time there were five severe epidemics. You will understand what I mean by severe epidemics when I tell you that they caused more than

one hundred and fifty out of every thousand deaths from all causes ; an enormous percentage.

So far from decreasing towards the end of last century, as has been stated, the most fatal year of smallpox in England was the year 1796, in which year no less than 184 persons out of every 1000 who died, died from smallpox, and the five severe epidemics all occurred during the last half of the century; so you see that at the end of last century smallpox was not decreasing. On an average during the last century it caused in England one death out of every twelve from all causes, and it killed about one out of every five it attacked. It was a disease especially fatal to children. Like scarlet fever, measles, whooping cough, and diphtheria, it was far more fatal to children than to adults. It is calculated that it caused half the deaths of children under ten years of age. Dr. Guy says, speaking of the statistics of this disease, "If I read the figures aright they point to a disease always specially greedy of the blood of children, but sometimes feasting upon them to repletion, and then waiting with cruel patience till the lapse of time had provided a fresh repast."

It is rarely that people have smallpox more than once ; but yet there are not a few cases on record where the same person has had it twice, and a certain number three times, and even more, so that it is at any rate possible to have it more than once ; and when a person has it twice, very frequently it is worse the second time than the first time, and not unfrequently he dies of it ; so that we may fairly conclude that persons who have it

twice, or three times, are persons who, for some reason or another, have a natural susceptibility to this particular disease.

Now, the first thing that was done with the view of diminishing the mortality from smallpox was a most extraordinary one. Where it was found out nobody knows. No doubt it was in the regions from which smallpox came, viz., from the East. Smallpox came from Asia. It was found in Europe in the sixth century after Christ, brought by the Saracens ; and it was taken from Europe to America by the Spaniards. It was found that if a person were inoculated with the poison of smallpox he was not so likely to die as he was if he caught the disease in the ordinary way, and inoculation was practised, nobody knows how long, in various parts of Asia. It was introduced into Constantinople in 1673, and from there it was brought to notice in England in 1717 by Lady Wortley Montague. She writes, "Every year thousands undergo this operation, and the French Ambassador pleasantly says that they take the smallpox here by way of diversion, as they take waters in other countries."

The practice of inoculating people with the poison of smallpox was tried under the sanction of the Royal Society upon six condemned criminals. I mention this because it shows that in 1717 they had the good sense to make criminals useful. I must confess that if I were a condemned criminal I would rather die of poison than be hanged. It is curious to notice the steps they took ; they first tried it upon these criminals, "next

five pauper children of St. James's; then the children of a few families of distinction; and, to crown all, their Majesties, acting on the cautious advice of Sir Hans Sloane, had all the royal children submitted to the operation." (Dr. Guy.)

I submit that that is a most extraordinary fact that they should take the poison of the most abominable disease that the world has ever seen and inoculate people of all classes of society up to the Royal families of Europe with it. Now what can that mean? There is no way of getting out of it except this, that the disease was so widely spread that, practically speaking, the whole population were certain to take it; and it shows us that it was not worth while to run the chance of not getting it. What would anybody say if I were to propose now to inoculate people with scarlet fever; they would say that it was a monstrous proposition, and why? because the whole population is not obliged to have scarlet fever, it does not disfigure people, it does not cause so many deaths as smallpox did; the only way we can account for inoculation being practised is that the whole population were so imbued with the dread of smallpox that they would rather do anything than run the risk of catching it, otherwise it is the last thing you would expect anybody to do—to inoculate themselves and their children with the poison of such a terrible disease.

There is no manner of doubt whatever that the liability to die from the disease was much less when it was inoculated than when it was got in the ordinary way, and you can partly understand this by the following

considerations: If you catch a disease it is quite clear you are in a state in which you are fit to take it, but if you are deliberately given the disease you run the chance that you are not in a condition in which you would catch it, and so you run the chance of being given the disease when you are best able to withstand it. And whereas natural smallpox killed one in every five, inoculated smallpox killed but one in every fifty at first, and afterwards only one in five hundred, when they knew the proper precautions to take. So that the person inoculated was much less likely to die from it. But, on the other hand, he became a centre of infection, because he had the disease, and other people could take it from him; so the centres of infection being multiplied, the number of epidemics during the period when inoculation was practised was greater than before; but whether the actual mortality was greater or less during the inoculation period is a matter of dispute. Dr. Guy decides that the mortality was less, and that inoculation, in spite of spreading the number of centres of infection, actually lessened the number of deaths from the disease. Some other writers are of opinion that the number of deaths during the inoculation period was greater in proportion than the number of deaths before, and that inoculation of smallpox was a danger to the community.

Inoculation with smallpox is now illegal, and rightly so, for this reason: If you or I choose to be inoculated with smallpox we have no right to expose other people to the chance of catching it.

A somewhat similar disease to smallpox affects other

animals than man; there is a disease among cows called the cow-pox, one among horses called the horse-pox, and one among sheep known as the sheep-pox. Now, at the end of the last century, there was a prevalent belief among the peasants in Gloucestershire that people who had had the cow-pox could not catch smallpox, and they were not afraid of it: no doubt many persons heard this, but it required a man to turn that fact to advantage. That man was found in an English medical practitioner named Jenner, who seized upon the idea prevalent among these peasants, and in 1795 began some experiments, of which, in 1798, he published the results. He tried inoculating persons with matter from one of the vesicles of a cow or calf attacked with cow-pox, and he made some very conclusive experiments of which people are not generally aware. He inoculated persons who had had the cow-pox (dairymaids and others), and persons who had been vaccinated, with smallpox virus, in some instances more than once, and found that they were not capable of taking smallpox even when the poison was put into their blood.

He tried vaccination from a person who had caught cow-pox from the cow—from the cow directly, and afterwards from the person who had been inoculated from the cow, and found all equally successful.

I could give other instances of experiments made while inoculation was legal to prove that persons who were inoculated with cow-pox were not able to take smallpox either by inoculation or contagion, and it was considered at that time to be distinctly proved.

We do not needlessly make experiments of that kind, and it would not be justifiable now needlessly to expose persons to the infection of smallpox, only I want you all to know that when vaccination was introduced, before it was made obligatory, experiments were made on a very large scale indeed. A pamphlet was published of experiments made by various medical men, and a law passed making vaccination gratuitous, but not obligatory; this, I think, was in 1844; and in 1853 vaccination of infants, before they were three months old, was made compulsory. The result of this, up to the year 1860, was published for us by the report of the Smallpox and Vaccination Committee of the Epidemiological Society. The average annual number of deaths in England from smallpox during the three years before the vaccination laws was 11,944, the average annual number of deaths in England during nine years while vaccination was gratuitous but not compulsory was 5221, the average annual number of deaths in the third period, from 1853 to 1860, when vaccination was compulsory, was 3234.

Mr. Simon calculated some time ago that the death-rate at that time among unvaccinated people varied from 14½ per cent of those attacked to 53⅘ per cent, and the death-rate of vaccinated people varied from ½ per cent to 12½ per cent; and Mr. Marson, who was for many years resident-surgeon in the smallpox hospital, says that the average death-rate among vaccinated people was about 5¼ per cent of those attacked.

Suppose I put it in this way then: I told you, you

will remember, that in 1796 the smallpox caused 184 deaths out of every 1000 deaths from all causes. Suppose we take 50 years at a time, from 1750 to 1800 there were 96 deaths from smallpox out of every 1000 deaths ; from 1800 to 1850, including part of the inoculation period and part of the gratuitous vaccination period, there were 35 deaths out of every 1000 ; from 1850 to 1860, when vaccination had become compulsory, there were but 11 deaths out of every 1000. These are figures which no amount of argument can explain away. You may write a book full of sophistry of all kinds on the subject, but no person of any sense would believe in any reasons that do not take into account the facts proved by these figures.

A few more figures. In 1853, before the compulsory law was passed, a return was presented to Parliament showing the mortality from smallpox in various places in the United Kingdom where vaccination was practised among people sufficiently educated to avail themselves of it while it was gratuitous but not compulsory, and showing at the same time the mortality in various countries abroad where vaccination was directly or indirectly compelled. It showed in London 16 deaths out of every 1000, Glasgow 36, Connaught 60, Edinburgh 19 to 20, Limerick 41, all Ireland 49, and in England and Wales 22, the smallest number thus being in London. These were the number of deaths which occurred in England when it was proposed to make vaccination compulsory. The largest return that was given from abroad, in countries where vaccination was

directly or indirectly compulsory, was for Saxony, viz., 8½. Several countries abroad had been much before us in this matter—we do things slowly but surely—but many countries had turned vaccination to use, and the numbers vary downwards, through Westphalia 6, Bavaria 4, Sweden 2·7, Venice a little over 2, Bohemia and Lombardy 2; so that at that time, in 1853, before our compulsory Act was passed, there were actually countries in Europe where the number of deaths from smallpox was reduced to 2 out of every 1000 deaths from all causes. I mention this to show you that there was sufficient reason at the time for the passing of the Compulsory Vaccination Act. Dr. Jenner himself believed that by vaccination smallpox could be stamped out, and he was one of the few discoverers who lived to see, to a very great extent, the fruit of his discovery and its value recognised.

In Baron's *Life of Jenner* we are told, "from the year 1762 to 1792 the number that died of smallpox in the Danish dominions amounted to 9728. About the year 1802 vaccination was first introduced, and the practice became general but not universal; however, 58 persons only died of the smallpox to the year 1810. Vaccination, by command of the king, was now universally adopted, and smallpox inoculation prohibited, and from the year 1810 to the year 1819, not a single case of smallpox has occurred."

It was then clearly shown by Jenner himself that when cow-pox was inoculated into a human being, that person was not susceptible to smallpox either by inocu-

lation or by exposure to the poison; and there is no instance of a vaccinated person getting smallpox until about fifteen years after vaccination was first introduced, but about that time there gradually came to be instances of vaccinated people getting smallpox. And so it came to be seen that a certain number of years after being vaccinated people required to be vaccinated again, and for a long time there were a lot of very strange ideas afloat, such as that we required to be vaccinated once in every seven years. But to make a long matter short, I may tell you at once that the fact is that after infant vaccination people only require to be vaccinated once again at about the age of 15 or 16. I must give you one or two instances showing the results of vaccination and of re-vaccination. Dr. Balfour tells us that after vaccination was made compulsory in the army and navy, in the dragoon regiments and guards with 44,611 men, between 1817 and 1836, out of 627 deaths only 3 were from smallpox. In the regiment at Gibraltar, of the same strength, out of nearly 1300 deaths only 1 was from smallpox. There are plenty of instances on record where troops subjected to compulsory re-vaccination were completely protected from smallpox—did not in fact have a case of smallpox among them—while the natives died by hundreds from that disease. Now Malta gives an excellent example of the protection of re-vaccination. During the 21 years from 1818 to 1838, the British troops, numbering 40,826, only lost 2 men by smallpox. In 1830, in Malta itself, 1 in every 12 persons was attacked

by smallpox, and 1 out of every 85 persons in the island died; but among the military, including wives and children, only 1 out of every 188 was attacked, and only 1 out of every 682 died of it. The Bavarian army, too, gives a remarkable example of the power of re-vaccination. From 1843 to 1857, 14 years, there was not a single case of unmodified smallpox in the army, nor a single death from smallpox. The nurses in smallpox hospitals also give proof of the power of re-vaccination. Mr. Marson, in his evidence some years ago, tells us that during an experience of 36 years of the London Smallpox Hospital, he has never had a case of a nurse having smallpox, because he re-vaccinated them all within three days of their arrival. During the last epidemic, out of the number of nurses in attendance, amounting sometimes to 300, there was scarcely any case of smallpox, and the few that occurred were cases of nurses or attendants who through the hurry of business had not been re-vaccinated.

It has been quite clearly shown that people can be vaccinated well and badly; that good or bad vaccination depends upon the number and kind of marks produced. Mr. Simon showed this some years ago by computation from statistics of the London Smallpox Hospital for 25 years. He showed that the mortality from smallpox among vaccinated people varied from less than 1 in 100; and among the people who died were some who, though stated to have been vaccinated, had no marks at all.

I will just rapidly read the figures :—

				Died per cent.
Of persons vaccinated but having no marks				21 to 22
„	„	and having 1 mark	.	7½
„	„	„	2 marks,	little over 4
„	„	„	3 „	1⅓
„	„	„	4 „	less than 1

A few words about the last epidemic in London in 1870-72.

This epidemic was exceedingly virulent, and extremely fatal. From a paper read by Dr. Grieve before the Epidemiological Society upon "Smallpox," I find that the rate of mortality among all the cases treated at the Hampstead Smallpox Hospital, was between 19 and 20 per cent; that is a very high percentage. There came to that hospital 6221 people during the epidemic, and it was found that of unvaccinated people over 51 per cent died, and of vaccinated people only 11·4 per cent. It was also shown that the mortality among vaccinated people depended upon the number of scars they had. Vaccination is not considered to be efficiently performed unless at least two marks are produced; and if four good marks are produced the person may be considered, practically speaking, to be protected from smallpox until the age of 12 or 15.

Now among these 6221 cases that came into the Smallpox Hospital only three cases presented proofs of re-vaccination, and these were mild cases. Experience thus shows quite clearly that cases of smallpox after re-vaccination are rare, and much less severe.

During that same epidemic, taking all the hospitals together, there were about 14,000 cases treated in London, and out of these 14,000 there were only four that showed proof of re-vaccination, and these were all mild cases.

I will just take the instance of people under 15. Out of 3085 consecutive cases in the Homerton and Stockwell Hospitals the mortality among those under 15 who were unvaccinated was 41 per cent, the mortality among those who had bad vaccination marks was 12 per cent, and the mortality among those who had only one vaccination mark was only 1½ per cent; and, to crown all, 277 cases under 15 years of age had two or more good marks, and there was not a death amongst them.

In Birmingham during that epidemic the mortality was 12·3 among those described as vaccinated, and 48·9 among those unvaccinated, and 16·45 per cent of the total cases reported; and the mortality was less than in the London hospitals. The severity of the disease was much less in those well, than in those imperfectly vaccinated; and not a single death of a re-vaccinated person occurred.

A word or two about the epidemic that we have at present. In 1876, 735 people died from smallpox in London. Of these some are reported as vaccinated, some as unvaccinated, and of some the certificates give no information. So that there may be no misunderstanding I will not take that whole number, because it includes doubtful cases. I will take the 338 who died in hospitals, as we know of those whether they were

vaccinated or not. Out of this number 204 had not been vaccinated, and 134 had been; that is to say, 60 per cent had not been vaccinated, while 40 per cent had been; in other words there were 20 per cent more deaths among the unvaccinated than among the vaccinated people in the smallpox hospitals of London, although the vaccinated people in London are about nine times as numerous as the unvaccinated. Now we will take the completed cases in the hospitals, that is, cases either cured or in which death ensued. There were 1377 cases, 1018 vaccinated and 359 unvaccinated. Of the 1018, 134 died, and of the 359, 204 died; from which we see that a little over 13 per cent of vaccinated people died, and nearly 57 per cent of unvaccinated; that is the experience of 1876.

Let us just glance at the statistics from Sweden which are often pointed to as conclusively proving the value of vaccination, though there has been an attempt to explain them away.

From 1749 to 1809 inclusive, 61 years, during which vaccination was not practised, there was only one year in which the deaths in Sweden were under 1000; every other year they were over 1000, and in nine years of that period over 10,000 in each year. From 1810 to 1872, 63 years, when vaccination was practised, there were 48 years in which the deaths were under 1000 and not a single year in which they came to 10,000, or even to 3000. I think these are facts about which there is no possibility of adverse explanation. Again, the greatest number of deaths in any year in the first

period of 61 years was 16,607, and the greatest number of deaths in the second period 2488; the least number of deaths in any year in the first period was 671 and in the second 2; these are the main facts of the Swedish statistics.

As it is sometimes stated that other diseases can be conveyed by vaccination, I should like to quote to you from a pamphlet entitled "A Vaccination Controversy," being letters between the chairman of the Anti-vaccination Society and Dr. George Ferguson of Cheltenham.

Dr. Ferguson says—"Vaccination does not communicate other diseases. Mr. Marson has vaccinated 50,000 times and has never known of such communication. Sir William Jenner, Sir James Paget, and Dr. West of the Children's Hospital, Ormond Street, London, all testify to the same fact, and Dr. West during 17 years had 26,000 children under his care from whom to draw conclusions." On the other hand, it is quite certain that there have been one or two exceedingly rare cases where persons have not been properly vaccinated and bad results have followed; this has been shown by a man who is a very strong advocate of vaccination himself, Mr. Jonathan Hutchinson.

I am glad to find that this matter has been lately investigated by a Board of Guardians in a part of the country which has been noted for its opposition to vaccination; I will read you the account given in the *Local Government Chronicle* of April 14th (1877).

"SKIPTON—VACCINATION INQUIRY.—In consequence of assertions made by the anti-vaccination agitators of

this part of Yorkshire, the Skipton Board of Guardians, about two months ago, appointed a committee, composed partly of guardians opposed to vaccination, to inquire into certain alleged cases of injury from vaccination, which the opposing party of the board were in the habit of referring to as an argument against vaccination. After much deliberation the members of the committee have drawn up a report in which they state the result of their investigation. To facilitate the investigation, advertisements were inserted in the local papers, asking individuals for information of supposed injury from vaccination. In reply, thirteen cases were adduced, but the report states that they were greatly exaggerated, and the majority of them were reported by persons not related to the sufferers. Except in one case of rash, in respect of which the physician consulted could not positively say that all the symptoms were owing to vaccination, the committee have come to the conclusion that no person reported to them has suffered in consequence of vaccination. Four cases looked very strong from the reports, but upon investigation it was found that in two instances the ailment was not complained of until two years after re-vaccination; and it was proved, by communications from the medical men who had attended the cases, that the illness had nothing whatever to do with vaccination, but appeared to be hereditary."

That is a most valuable report, coming as it does from a committee composed partly of anti-vaccinators.

Infant vaccination should be practised from arm to arm, which is much more successful than from points, or

from vaccine matter kept in tubes, though I must not omit to tell you that vaccine matter kept in tubes is subjected to most careful tests, and not a single tube which shows any signs of anything but pure lymph is sent out from the vaccination department.

With regard to vaccination from the heifer, it has been successfully introduced into Belgium, and it is quite possible that it may be introduced into this country ; I do not believe it will ever replace arm to arm vaccination, though I do not see why they should not be worked side by side, so that if any person has a kind of prejudice against human lymph there is no reason why he should not be vaccinated from the calf.

There is one country in Europe where the vaccination of infants *and re-vaccination* are now compulsory. In Prussia there were no compulsory vaccination laws for the civil population until 1874, but the mortality from smallpox in Prussia was so enormously greater than in German States where vaccination was compulsory, that in March 1874 a law was passed making the vaccination of infants, and the re-vaccination of children of riper years, compulsory *throughout the whole of the German Empire.*

Let me finish this lecture by quoting to you a few lines from Dr. Aitken.

"It is thus clearly demonstrated how vaccination has thrown the *ægis* of protection over the world ; and how ample, how great, and how efficient that protection may be. It has been shown to diminish mortality generally, and the mortality from smallpox in particular

both in civil and in military life, at home and abroad, and just in proportion as it is *efficiently* performed. It has been shown to diminish the epidemic influence; it has been shown to preserve the good looks of the people; it has been shown that it tends to render smallpox a mild disease compared with the same disease in the unprotected; it confers an almost absolute security against death from smallpox; and lastly, it has been shown to exercise a protecting influence over the health of the community generally. On the other hand, it is no less amply proven that 'wheresoever vaccination falls into neglect, smallpox tends to become again the same frightful pestilence it was in the days before Jenner's discovery; that wheresoever vaccination is universally and properly performed, smallpox tends to be of as little effect as any extinct epidemic of the middle ages.'—(SIMON.)"

LECTURE XIX.

COMMUNICABLE DISEASES.

Among diseases that are very largely spread in communities, there is one great class of diseases which do not travel from the places in which they are found; they prevail very largely among the people where they exist, but do not travel from place to place; they cannot be given by one person to another. Such diseases are—consumption, scrofula, rickets, marsh fevers, rheumatic fever, and a great many others. These diseases go by the name of *endemic* diseases, from two Greek words meaning in or among the people.

Then there is another great class of diseases which I am going to speak about, which can be taken about by persons suffering from them, and spread by many other ways, and which, under certain circumstances, spread from place to place. Many of them are called *epidemic* diseases, epidemic meaning upon the people. I shall call them all simply *communicable* diseases, because communicable is a word which does not imply any theory, as it is quite certain that these diseases may be communicated in some way or another, either directly or indirectly from one person to another, and so are taken from place to place. Sometimes they are called contagious or infectious diseases, but as these

words both imply some theory, and as there is great confusion, some diseases being said to be contagious and others infectious, I will not use either of these terms, but we will call them communicable diseases.

The first of these diseases, which is perhaps the best type, is the disease to which I devoted the whole of last lecture,—there is no doubt that small-pox is a communicable disease. And then there are kindred diseases, such as scarlet fever, diphtheria, measles, whooping cough, typhus fever, and enteric, or typhoid fever. These are diseases of the same kind, although there are differences between them, and we will consider them all together. This set of diseases is characterised in a very peculiar manner. When a person has once had any one of them, he is very unlikely to have it again. They are diseases of definite durations, divided into well-defined periods, one of the most remarkable of these periods being what is called the period of incubation, and they are accompanied by fever.

After a person has been infected by the poison of one of these diseases, it does not break out at once, but a certain period elapses, which is called the period of incubation, while the disease is, as it were, hatching itself in the person who has been infected; that is a very remarkable fact.

Then there are diseases which have somewhat different characteristics, but still they are communicable from one person to another, and are taken about from place to place. These are the leprosy of ancient times, described in the Bible—whatever disease that was, I

think any one who reads the chapters relating to it must see that it was a communicable disease: the plague, of which I hope we are never likely to see anything again, and cholera.

Then there is another class of diseases which are certainly communicable, but which differ from those just described in several ways. These are known as—erysipelas, hospital gangrene (found in over-crowded hospitals), blood-poisoning, and two or three others; also certain diseases which are communicable, and for which special Acts of Parliament have been framed with the view of preventing their spread.

Among the lower animals, also, there are diseases which are communicated from one to the other, and may be communicated from the animals to men. One of these is an exceedingly fatal disease, known as malignant pustule, which, when communicated, is almost always fatal; glanders, found mostly among horses; and, lastly, the disease known as sheep-pox, cow-pox, and horse-pox, which, when communicated to human beings in the way I described in the last lecture, produces a mild disease which goes by the name of vaccinia, which I showed you prevented attacks of smallpox.

These are some of the more important diseases which are communicable. Now, in each case, when one of these diseases is communicated, something, which may be called the poison of the disease, passes from one person to the other, and this poison may be given directly from one person to another, or carried about in various ways. It has been shown over and over again

that it can be carried in clothes. This fact, taken by itself, is sufficient to show us that there is some material thing which can be taken by one person and given to another, and when given to that other person, may cause the disease in him. These materials can be carried about in clothes, in water, in air, and various other media. We then come to the conclusion that there are such poisons, and that they are material substances. We have gone a great deal further than this. Secretions containing these poisons have been subjected to various kinds of examination; for instance,—vaccine lymph, used for inoculating persons with vaccine matter, and other blood poisons, have been subjected to examination, and the conclusion come to is, that the poison is a solid substance, and not a gas, nor dissolved in the liquid secretions that have been examined, but is in the form of solid particles, and can be separated out, leaving the liquid behind. The solid particles in vaccine matter can be separated out from the fluid, and it has been shown that the solid particles contain infectious matter, and that the liquid in which they are suspended does not. It has also been shown that the poisons of these diseases are not volatile; when liquids are subjected to evaporation, and the evaporated liquid is caught, that liquid does not contain infected material, but the infected material is in the solid substance remaining behind; so that you see, by direct scientific experiment in certain of these diseases the character of the poison has been shown; this, however, only up to a certain point.

It has long been observed that the phenomena of these diseases resemble in various ways the phenomena which occur during decomposition or putrefaction of organic substances; and it has been shown by several observers, notably, you will remember, lately by Professor Tyndall, that putrefaction does not occur unless certain material particles are in the liquid, or get into it from the air.

One resemblance of these phenomena to putrefaction that I will point out is, that the poisons of these diseases and the bodies which produce putrefaction alike multiply indefinitely in suitable media.

Another thing to be mentioned about these poisons, to put it in homely language, is, that they always breed true, that the poison that comes from small-pox is not capable of producing scarlet fever, or that the poison from a child suffering from measles does not give another child whooping cough or diphtheria; and so you see that there is something definite about each of these poisons, which gives it a character that we call specific; hence these diseases go by the name of specific diseases. Lastly, these poisons are destroyed by suitable agents; for instance, we have a large amount of evidence supported by remarkable scientific experiments, that heat, a little above the boiling point of water, will destroy the poisons of these diseases, and that is another analogy between the poisons of these diseases and the agents which are present during putrefaction, which we know are living things; so we can gradually, without ever actually seeing them, arrive at the conclusion that the

poisons of these diseases most resemble the bodies that are present during putrefaction, and that like these they are living things. If we accept that we come to the conclusion that these poisons are, in the first place, actual particles of solid matter; in the second place, that they are organic; and in the third place, that in all probability they are living things; and in connection with their being living things, I must point out the important consideration that the first stage in all these diseases is the stage of incubation; that, after a dose of the poison, whatever it is, has been taken, the disease does not develop itself until that poison has had time to grow. Now, contrast that with the action of any ordinary poison that you know of; for instance, if I take a dose of prussic acid, it does not wait for three or four days before it kills me; it kills me instantly, or almost instantly; and the same can be said of arsenic, or organic vegetable poisons, as strychnine, or morphia; a sufficient dose of either kills a person almost instantly; it takes merely the time during which it is being absorbed; so you see that the poisons of these diseases differ in a very peculiar and remarkable manner from other poisons with which we are acquainted.

We will consider first what we know about the origination of these poisons; what we know about the media by which they are conveyed from one place to another; what we know about the circumstances which favour the spread of one more than another, and the methods for the prevention of their spreading.

It has been maintained that every one of these

poisons may originate at any time and anywhere under suitable circumstances. One of the greatest of physicians, Dr. Trousseau, said that the fact that all these diseases must have originated some time or another somewhere shows that they may originate at any time anywhere if conditions are suitable; that appears a logical way of putting it, but still that statement implied a theory which requires a great deal of proof. You may almost as well say that wheat originated at some place, and that, therefore, it may originate elsewhere under suitable conditions, the only difference being that grains of wheat are larger things than the poisons of these diseases. But you will now find very few people who will go so far as to tell you that the poison of any one of these diseases may originate at any time anywhere; as a matter of fact, the majority of people believe now that the poisons of most of these diseases do not originate at any time anywhere, but come from a previous case; that scarlet fever, for instance, is not got by anybody, unless he somewhere or another has come into communication with the poison derived from a case of scarlet fever.

I want you to notice, that one after another of these diseases has been put out of the category of diseases which arise spontaneously, and it has now been brought down by almost all observers to the diseases known as typhus and typhoid (or enteric) fevers, with a few others of less importance. It is admitted that these diseases are communicable from one person to another, with the single exception of typhoid or enteric fever; but there

are persons who believe that such communication does not occur in the case of typhoid fever, or if it does, it is a very rare thing, so we may say that it is admitted by most persons that the majority of these diseases are only caught by contact.

The poisons of these diseases are carried about suspended in the air, in the dust, and, so far as we know, may be carried considerable distances in this way, but in most of the diseases the atmosphere around a person who is suffering from the disease does not give it to the persons in the same place beyond a very small distance. It was observed some time ago, in the last century, that the atmosphere around a smallpox patient is only infectious at a little distance, and in typhus fever the distance is still smaller; that, in fact, the poison given off into the air around became so diluted in the air that it is at any rate not usual for persons to take the disease except at a very short distance from a person suffering from one of these diseases.

We see from this that it is of the highest importance that the rooms in which persons are suffering from these diseases should be well ventilated.

Water is an important medium for the communication of these diseases. So far as we know, the poisons of any of them may be taken in water, but it is especially so in the cases of cholera and typhoid fever. And as this is so, they may be contained in milk which has been mixed with water containing the poison.

The poisons may be carried about in clothes. There are on record many instances where the poisons of scarlet

fever, cholera, yellow fever, and several other diseases, have been carried about in clothes.

The poisons, most notably those of cholera and enteric fever, which are got rid of from the body by means of the intestinal canal, get into sewage, and so the sewage gets infected. The poisons are then spread to human beings in one of two ways, either by sewage getting into the water which human beings drink, or by the poisons, through the shaking about of the sewage and the decomposition that goes on, being carried up bodily into sewer air. Some very instructive experiments made by Dr. Frankland have shown that particles may be carried up and suspended in the air. These particles may be carried up and suspended in the air in the sewers and drains, and by methods of communication get into the houses, or into the drinking water by means of the waste-pipes of water cisterns.

These poisons may be carried about by rats, which make their way from bad drains into the basements of houses, and to different parts. This is a method of communication of these diseases which has been too much overlooked. In my opinion the presence of rats ought always to be considered dangerous, as not only may the rats carry the poison of these diseases, but wherever a rat can go foul air can find its way, and that air may contain the poison of one or other of these diseases. This, I believe, is really a very common way in which these diseases are spread.

Another method, which I have long been of opinion is a very important one, and one that ought not to be

overlooked, is, that these poisons may be carried about by flies. It has been shown by a very admirable series of experiments made in France by Dr. Raimbert, that the poison of malignant pustule, a disease which affects cattle, can be carried about by flies, is commonly carried about by them, and by that means may be communicated to human beings. Raimbert, moreover, examined the poison, allowed flies to settle upon poisoned materials, caught the flies, examined them, and found substances containing these poisons upon their feet, and he allowed these flies to infect animals, and showed that these poisons passed readily through the mucous membrane, and were readily absorbed through the mucous surfaces, and in one case through the skin, thus proving that it was not necessary, as was commonly supposed, for an animal to be wounded in order to take the poison. He further showed that the flies that did this were not, as commonly supposed, stinging flies, but, on the contrary, common house flies, blow flies, flies provided with probosces, commonly regarded as not only harmless, but as scavengers to remove filth.

This matter has not been taken up at all, but I noticed, I think, three years ago in a number of the *Lancet* an account of an epidemic of smallpox in a place which was observed at the time to be accompanied by the inroad of an enormous army of flies. It struck me at that time that it was just possible that in that instance, and in one or two other instances, it may have been spread by flies. It has struck me since much more forcibly in noticing the way in which flies

abound in hot weather in hospital wards, and settle upon suppurating wounds, and fly from one patient to another, settling upon different parts of the body, especially upon the orifices where the mucous membrane comes to the surface, that it is quite possible that flies may disseminate these communicable diseases, especially such as erysipelas, hospital gangrene, and perhaps smallpox, in which there are crusts and scabs, which the flies may carry with them in a way which has been entirely unsuspected.

Now, the poisons of these diseases are separated from the bodies of infected persons in different ways; in almost all cases the poison is eliminated from all the excretory organs, but in certain of these diseases it is eliminated by one or other of the excretory organs by preference. For instance, in the case of smallpox, scarlet fever, and measles, it is got rid of from the skin and certain mucous membranes. In scarlet fever and diphtheria it is got rid of from the throat; in typhus fever it is got rid of by means of exhalations of the breath, and from the skin. In whooping cough it is coughed into the air by exhalations from the lungs; by the mucous membranes of the lung passages it is breathed out into the air. In enteric or typhoid fever, as in cholera, it is almost entirely got rid of by means of discharges from the intestinal canal. Some of these poisons, you see therefore, leave the person infected in such a manner as to get into the air around, and into the bedclothes, in a kind of fine cloud of dust, although it is true that in all these diseases the con-

tagious atmosphere is only close round the patient, and the disease is not communicated from one person to another except at a small distance. In the case of the other diseases, such as cholera and typhoid or enteric fever, in which the poison does not get out into the air around, but leaves the body by means of discharges from the intestinal canal, these diseases have often not been recognised as contagious or communicable.

What I want you to understand is that the difference between the communication of the poisons of these two classes of diseases is not in the poison, or in the nature of the poison, but in the way in which the poisons leave the body of the infected person. I want you to come to the conclusion that the last mentioned diseases, cholera and typhoid fever, are just as essentially communicable diseases as scarlet fever and smallpox.

The diseases which are most obviously communicable have among them diseases which it is supposed every one must take. They are diseases that especially belong to children; the reason is that they are diseases which a person only has once in his life as a rule. So you see they especially affect children, because as soon as a child is exposed to the poison of one of the diseases he is most likely to take it, in which case he does not, as a rule, get it again later in life, and if he does not take it then, it is very likely that he will never have it at all. The only one of these diseases that is no longer specially confined to children is the most dreadful of them—viz. smallpox, although it was formerly the most fatal disease of childhood, and killed half the children

under ten years of age before vaccination was practised. It is now rare for a child who has been properly vaccinated to have smallpox.

The idea that children must have measles and whooping cough is an entire mistake. If these diseases do not kill children directly, they kill a very large number indirectly, and maim a great many more by leaving them liable to diseases of the respiratory organs; hence, if possible, children should be prevented from catching them. Many people will allow their children to take measles. I consider that they are wrong, and that they ought not deliberately to expose their children to that which may kill them; they have no business to assume that their children will get that disease, and must have it, and I am sure no child has ever been the better for having had it, while many are injured for life.

Now, all these diseases spread more where there is overcrowding, and so they always spread in large towns. You can understand, from the various ways in which these diseases spread, that they are more dangerous where people are crowded together, but this is especially true of typhus fever, which is only at home in very crowded parts of towns. It does not spread in other parts if it is introduced, and in fact the infective distance of typhus fever is very small. Although it is an extremely infectious fever it does not spread from one spot to another, through persons going occasionally to see the patient, nor does it attack the attendants if they do not handle the patient. It is a fever that was formerly known as jail fever, and was given other names,

according to the overcrowded places in which it spread, and it is one of the diseases of which we are told that the poison can originate spontaneously.

We have been gradually reducing the number of diseases of which we believe the poison originates spontaneously. Now, typhoid, or enteric fever, has only been recently separated from typhus fever. It has been shown clearly that whereas typhus fever spreads especially in overcrowded places, and among the poor and destitute and starved, typhoid fever spreads, on the contrary, wherever the matters that are discharged from the intestines of human beings are not got rid of from houses or towns. The distinctive characteristics of these two diseases I will not enter upon, but they are so different that it is a perfect mystery to us now that they should ever have been confused. We have seen, too, the different ways in which these diseases spread.

We are told on very high authority that the poison of enteric fever is capable of originating *de novo* in filth of various kinds, that you only have to have a certain amount of decomposing matter under certain circumstances, and the poison of this disease can be produced and given to human beings. This statement is supported, too, by the assertion that in the majority of instances where cases of typhoid fever arise you are not able to find where it came from. Now, with regard to that, I would point out to you that it is a disease a person may suffer from for weeks, and with which he may go about from place to place without knowing that he has it. A person may go through it to the third stage,

and then fall down dead with it, and the disease may be regarded as heart disease. Now, notice that wherever he has gone for the last three weeks he has been spreading the poison of typhoid fever.

These are a few facts which show you that it is a ridiculous impossibility to expect that we can trace the poison of this disease always to the place from whence it came. It may be mixed with milk in the Midland counties of England, sent up to London, and distributed to a number of houses in London. The connection between these may never be known, and there is no doubt that that method was never suspected until the recent epidemics of this disease occurred; and I put it to you whether we are in a position to say that we are able in a case of this disease to state that the poison was not derived from a previous case.

We are told also that this disease is not generally communicable from one person to another, because it is frequently taken to a place, and does not spread there; the answer to that is perfectly clear,—in those places precautions are taken to remove matters containing the poison. Smallpox, scarlet fever, and typhus fever, do not spread if proper precautions are taken, and that is why typhus fever does not spread in the West End of London, although it is taken there over and over again.

We can also bring forward arguments of another kind; we can point to places where filth has been accumulating for years, places, you would say, most suitable for cholera and enteric fever, if the poisons of these diseases are developed in decomposing animal

matters, and yet these diseases have not been there for years; the answer to that is, that all the conditions are not present. Now, on a certain day a person comes to one of these places ill with enteric fever, they do not know what is the matter with him, and he is attended, perhaps, for a week or two. As soon as they have found out what is the matter with him, a score or so of persons have already become infected with the fever, and it spreads over the place like wildfire. This shows you that the place was in an admirable condition for the poison of that disease to spread if it could have originated there, and though you may come to the conclusion that the disease was not there before because there was some missing condition, you must admit that the person who came there ill brought the poison.

I will now tell you a few practical methods to prevent the spread of these diseases.

The first method is by separating persons who are sick from the healthy community; that is the method pointed out by Moses in the 13th and 14th chapters of Leviticus, two of the most admirable sanitary chapters that have ever been written. One form of leprosy was undoubtedly an infectious disease, which some people have said was smallpox.

The sick people are to be separated, and so it is necessary to have fever hospitals. Mind these diseases do not spread from fever hospitals. There is no instance known of any of these diseases having spread from the London fever hospitals to houses in the neighbourhood, yet it is true that sometimes these diseases are found in

some of the houses in the neighbourhood, and especially in public-houses where they have been conveyed by the attendants; but there is, at any rate, not sufficient need to have the great amount of fear that people seem to have on this subject.

In London the different vestries and district boards are the sanitary authorities, and each of them is empowered to provide hospitals for infectious diseases when they exist.

But as a matter of fact the great fever hospitals, under the control of the Metropolitan Asylums Board, and intended for paupers only, are made use of by almost all classes. Many persons object to go to these hospitals because they are pauper hospitals, but I think when such a serious thing is concerned the matter ought to be separated from connection with pauperism. A person affected with an infectious disease ought to be taken to an infectious hospital whether he can afford to pay for it or not, but he ought not to be made a pauper of by that fact. (An Act since passed has accomplished this.)

I say, then, isolation is the first thing; the next is disinfection; by this I mean the destruction of the poison. We are perfectly certain now, by direct experiment, that the poisons of some of these diseases can be destroyed by certain agents. There are a good many agents that have been long in use as disinfectants. The first is dry heat; this is capable of destroying such of these poisons as have been experimented on, and it has been practically shown that heat is capable of destroying the poisons of all of these diseases. Practically the

baking of clothes in a disinfecting oven, raising the heat to about 240° Fahr., a temperature which will not singe the clothes, is sufficient. I do not mean to say, however, that burning the clothes would not be the safer and better plan of getting rid of infected articles if you can spare them, but when you consider the amount of clothing that would have to be destroyed during an epidemic of smallpox, you will see that this is often a practical impossibility.

I maintain, further, that it is a thing which need not be carried out. I have never known an instance where clothes, that have been disinfected in a hot oven, have been the means of spreading disease.

It has been shown that sulphurous acid gas, nitrous acid, and chlorine, are all agents that may be used for disinfecting purposes. Sulphurous acid is an agent that can be relied upon. For disinfecting masses of matters, both liquid and semi-solid, such as discharges from the intestinal canal, green copperas or sulphate of iron, in the form of a solution of a pound of green copperas to a gallon of water, is very effective. Strong carbolic acid is likewise good, and, under certain circumstances, chloride of lime.

When a person is suffering from one of these infectious diseases, the first thing to do is to change the air of the room as often as possible without causing any draught; that is best done by having a small fire in the room and the windows open in the house.

All articles, especially woollen drapery and curtains, should be removed from the room as soon as

the person is put into it, and they will not be infected if removed at once.

All discharges from the patient should be received in vessels containing a disinfectant, as carbolic acid, or better still, a strong solution of green copperas. The cup which is provided for the patient to spit in should also contain a disinfectant.

All bed-clothes, linen, etc., should be placed in water containing a disinfectant before they are taken from the room; pocket handkerchiefs should not be used, but small pieces of rag, which should be burnt. All glasses and cups used should be very carefully cleansed in hot water before being used by any one else.

Nurses should not wear woollen garments, but glazed cotton dresses, and should wash their hands in water containing chloride of lime before leaving the room.

In scarlet fever and smallpox, when the poison is given off from the skin, it is a very good plan to rub the patient with oil, or, better, camphorated oil; this is soothing to the patient, and it prevents the poisonous matter getting away from the skin and becoming diffused in the air around.

As soon as the patient is well enough he should take a warm bath, in which the whole of his person should be scrubbed, carbolic soap being used, and afterwards the bath should be repeated every other day until four or five have been taken. He should not be allowed to mix with other people until the skin is perfectly clean.

In enteric fever the discharges from the intestinal canal should be disinfected.

In cholera disinfection is much more difficult, owing to the enormous amount of discharge, but it is well in this, as in enteric fever, to adopt the precaution.

After a person has recovered, the room and articles in it require disinfecting. The best way to do this is to paste up the crevices of the windows and fireplace with paper, and then to burn in the room, in an iron vessel, some sulphur. The vessel in which the sulphur is burnt should be suspended over a bucket of water by placing it on a couple of stair rods or a pair of tongs, and the sulphur can be lit by a match, or, still better, by pouring spirits of wine on it and lighting that; the door must then be shut and paper pasted over the crevices outside. The sulphur will burn and form sulphurous acid in such a quantity that a person could not live in the room. It should be left for six hours, and at the end of that time it will have been sufficiently disinfected.

The paper on the walls should be stripped off and burnt, but the sulphur should be burnt in the room before this is done.

The walls of the room should be lime-whited, and the wood-work scrubbed well with water having chloride of lime or some other disinfectant in it; the ceiling should be lime-whited, and the room left unoccupied as long as possible.

Bed and bed-linen should be sent to the hot air chamber and baked.

In no instance where these precautions have been taken have I known the same disease to break out again in a room, and that is, I think, a proof that the method is a good one, and it is a method supported by some admirable experiments recently made with agents for the destruction of the poisons of epidemic diseases.

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